DISORDERS OF APPLE FRUITS IN AUSTRALIA

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COMMONWEALTH OF AUSTRALIA

Council for Scientific and Industrial Research

BULLETIN No. 238

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The Non-parasitic Disorders of Apple Fruits in Australia

By

W. M. CARNE

MELBOURNE 1948

Registered at the General Post Office, Melbourne, for transmission by post as a periodical

C.2193/48. J. J. GOURLEY, Government Printer, Melbourne

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Non-parasitic Disorders of Apple Fruits in Australia*

By W. M. Carne†

I. INTRODUCTION

Long experience with non-parasitic disorders of apples developed while on the tree, after pickling, and in and after cool storage, has shown the need of a standard nomenclature. Difficulty has been found in relating disorders found to those recorded in the literature. Doubt has often been felt that the same name used by different authors refers always to the same disorder. The same name has been used for disorders since shown to be quite unrelated. For instance McAlpine (1911-16) in his conception of bitter pit, included disorders which are consequences of watercore and boron deficiency as well as that originally called bitter pit by Cobb (1895).

The present work had its origin in England in 1936, where the author was then engaged in reporting on the condition of Australian apples on arrival and during subsequent marketing in the United Kingdom. A meeting of investigators was called, with representatives from England, New Zealand, South Africa, and Australia. The members were confronted with a collection of apples from Australia showing various disorders and were asked to name the defects. The meeting found itself unable to do so and invited the author to undertake the task of preparing a classification. This he attempted and the draft was widely distributed in 1938 and later. A request for criticism and amplification met with little response.

During the past ten years the author has added to his experience, in the light of which the original draft has been amended to its present form. For obvious reasons the classification now put forward covers only disorders found in Australian-grown apples.

The author's experience covers some six years in Western Australia largely given to field, laboratory, and cool storage work with apples. This was followed by four years of more intensive work on similar lines in Tasmania. In addition, he was engaged for three seasons (1931, 1936, and 1937) in reporting on the condition of Australian apples in England. Opportunity was then taken to see the disorders developed in English apples as well as those in fruit arriving in England from both the Northern and Southern Hemispheres. In the early summer of 1937 he visited the main apple-growing areas of Canada and was able to see some of the disorders developed in the growing period, notably those due to boron deficiency.

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* Typescript received October 28, 1947.

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Since 1937 his official duties have brought him into contact with apple disorders in all the Australian States, both in the orchard and after storage.

The present work has been prepared with the object of providing a standard classification and nomenclature for investigators in a difficult field. It is realized that with increasing knowledge both will inevitably need amendment in the perhaps not distant future. It is hoped, however, that this work may contribute to such an expansion of knowledge by providing a foundation on which to build.

The author acknowledges his indebtedness to many fellow workers. Of these his former colleagues H. A. Pittman and H. G. Elliot, in Western Australia, and more especially D. Martin in Tasmania, must be mentioned. His cooperation with the last-named still continues. His thanks are also due to Dr. R. N. Robertson for reading the manuscript and making helpful suggestions.

II. NON-PARASITIC DISORDERS OF APPLES DEFINED

The disorders included in the classification " non-parasitic " are those due to senility, defective nutrition, functional upsets known as physiological (or physiogenic) disorders, and chemical and mechanical injuries resulting from errors of husbandry or mechanical mishaps. They do not include disorders directly due to insects, spider mites, and other animal life (excluding man), or to fungi, bacteria, or viruses.

III. DESCRIPTION OF THE APPLE FRUIT

Apples vary in shape (oblate, conical, &c.), in length compared with breadth (flattened, elongated, &c.), in the presence or absence of a ridged or irregular calyx basin, and in colour &c. Nevertheless they all conform to one general plan. They are living structures which develop to maturity and then decline into senescence and death. Economically their value declines with senescence and ceases with death unless frozen, canned, dried, or otherwise preserved against deterioration.

The following description of the fruit is included in order to explain the terms used in this publication.

(a) *Main External Features*

Stem or stalk.—This varies considerably in length from under ½ inch to 2 inches according to the variety. It also varies in thickness and length within a variety and with the position of a fruit in a cluster, the centre apple frequently having a thicker and shorter stalk than the lateral apples.

Stem cavity or basin.—This varies considerably in depth and width.

Cheeks.—Excluding the calyx and stem ends, these cover the main surface of the fruit and their colour determines the colour of the apple. They are conveniently divided into the stem half and calyx half, *Colour.*—All apples are more or less green at first. Later the skin, mainly of the cheeks, may develop a brown, pink, red, or scarlet pigment or become brown through the development of a brown russet from the superficial tissues. Three types of colour are recognized:

(i) The ground colour which passes from green to cream or yellow as the fruit ripens.

(ii) The blush or pigment colour which masks the ground colour. It is dependent on the variety, exposure to light on the tree, and the climate in which the fruit is grown. The pigment is usually most strongly developed in climates with hot day temperatures, cool nights, and dewy mornings. In many varieties the surface may conveniently be divided into blushed and unblushed or slightly blushed portions.

(iii) The brown russet colour which overlies the ground colour in certain varieties. Russet development is determined by variety, is increased by cool moist climates, and is stimulated by certain spray treatments.

Calyx end.—This shows the remains of the flower calyx.

Calyx basin.—This is the depression in which the calyx is set. The basin varies in width and depth and in the smoothness or ridging of its edge.

Calyx tube.—This is at the bottom of the basin and connects it with the core.

(*b*) *Main Internal Features*

Those shown in an equatorial cross section (Fig. 1) are:

Skin.—This consists of cuticle and epidermal tissues and carries large numbers of pores or lenticels. These are openings loosely filled with corky tissue which permit gases and water vapour, but not water, to pass. They may become blocked and ineffective. The lenticels increase in number per unit of skin area from the stem end to the calyx end but not into the basin.

Cortex.—This is the main body of edible tissue.

Core.—This consists of:

(i) The core line or vascular ring, a faint, thin more or less regular vascular ring in which are ten large vessels in cross section.

(ii) The core flesh.

(iii) Five carpels or seed cavities. The most obvious feature of the carpels is their horny inner walls within which lie the seeds. Normally the carpels are closed compartments joined together at their inner edges. In some varieties, the carpels open at their inner edges and form a large central cavity (hollow or open core).

Examined in longitudinal section (Fig. 2), certain other internal features become evident. The core line unites with the stalk vasculars close to where the stalk enters the fruit. At the other end, the core line passes into the calyx tube. This calyx tube may be closed or open where it enters the core. In varieties with open cores, the calyx tube is usually open, thus allowing air to pass directly into and out of the core cavity. So long as the lenticels are functioning, respiration (breathing) and transpiration (loss of water) goes on through them. As the fruits develop there is a tendency, which varies with varieties, for the lenticels to become blocked and inoperative (English, Ryall, and Smith 1946). Blocking is most marked in varieties which develop a waxy bloom. Its occurrence reduces respiration and transpiration to that which can go on through the epidermal tissues, or through open cores. Granny Smith is a variety in which the lenticels become practically inoperative and Delicious one in which many continue to function (Hackney 1944).

IV. CHANGES IN THE APPLE FRUIT DURING MATURATION ON THE TREE

(*a*) *Definition of Picking Maturity*

Commercial picking maturity for apples may be defined as the stage in the development of the apple at which it will, if picked, develop and maintain good marketing qualities during a reasonable period of storage and marketing, the length of this period varying with the variety. For dessert varieties the objectives are good flavour and juiciness, together with an absence of defects such as rots, breakdown, and pit. For culinary varieties the objectives are firmness, a green ground colour, and an absence of astringency and the defects mentioned above. From the commencement of the season of suitable commercial maturity to its close, the keeping quality of the fruit tends to decline. At the same time the final dessert or culinary quality tends to rise and then decline.

It should be noted that commercial picking maturity relates to a picking period which varies in length according to the variety and to the intentions of the grower. Any variety may be picked early for cooking within a few days, later for common or long cool storage, still later for short cool storage, and when practically tree ripe for early dessert use. However, the great bulk of commercial production is picked according to its keeping quality and the proximity to markets as follows:

(i) *Early varieties* (December to February) are picked and marketed as early as possible after they are saleable, subject to an ability to maintain their saleable condition during the marketing period. The shorter the period between picking and marketing the earlier the fruit can be picked.

(ii) *Midseason varieties* (late February to mid April) are picked at a maturity suitable for storage up to three to five months in cool storage or shorter periods in common storage.

(iii) *Late varieties* (April to May) are picked at a maturity suitable for cool storage for four to six months.

The length of the safe commercial picking period varies with the variety. In early varieties it may be only a few days while in late varieties it is usually three or four weeks and may be more. Within a commercial picking period there is an optimum time at which fruit is of optimum maturity for commercial marketing, i.e., for storage consistent with development of good palatability. This time may and usually does vary between fruits on a tree, between trees, and between localities.

In this publication the terms picking maturity and optimum maturity refer to commercial picking as described above.

Over-maturity for commercial picking is reached when the period of good quality storage is too short for commercial purposes.

Commercial picking maturity can be recognized with reasonable accuracy for the fruit of good to heavy crops, by noting the ground colour changes and the development of juiciness. For light crops the selection of the picking time is more difficult. Picking on the basis of ground colour and juiciness will ensure the development of flavour but the storage life will be short. Picking earlier may lead to heavy pitting or poorer quality. The best period is short and may never be really good. As a general rule picking of light crops should be commenced about two weeks earlier than good crops grown under similar conditions of soil and locality. If not marketed promptly they should not be stored in either common or cool storage for more than a few weeks, the time being determined by observation of their behaviour.

(*b*) *Changes Accompanying Maturation*

Very immature fruit is characterized by:

(i) Relatively small size for the variety.
(ii) Dull green colour often with a brown to dull reddish flush on red or blushed varieties.
(iii) Hardness.
(iv) Relative dryness when cut.
(v) High acidity to the taste and a certain amount of astringency, both varying with the variety.

As the fruit matures the following changes take place:

The fruit grows rapidly in size, the rate of growth rising and then falling later. Under normal conditions the growth rate is declining at the commercial picking time but growth has not stopped. If growth has been slowed by drought and then revived by late rains the growth rate may be high at the usual picking time. The maturation growth in fruit size after about six weeks from blossom is a result of the enlargement of the tissue cells and intercellular spaces and not of the production of new cells.

Accompanying the size increase, changes can be observed in the skin colour. The green ground colour becomes lighter and brighter and eventually distinct evidence of changing to yellow can be seen. At picking time the ground colour of dessert varieties is always predominantly green but the dull immature colour should have at least " broken " or started to change. In the same way, the brown and red colour if present should have become brighter and nearer to the pinks, reds, &c., of mature fruit.

If the fruits are cut it will be noted that the seeds change from white through brown to mahogany, though these changes are not reliable guides to any particular stages of maturity.

As the fruit approaches picking maturity there is a sharp and marked increase in the flow of sap from cut tissues. Acidity also declines with increasing maturity but the taste cannot be relied upon to measure this, especially in acid varieties. The fruit also becomes softer, but this is more evident as it approaches ripeness as distinct from commercial picking maturity.

It is possible to distinguish an increasing edibility due to the softening of the flesh, an increase in its sugar content, and a decline in its astringency. In most cases, however, dessert fruit is far from suitable for eating at the commercial picking time, except in low acid varieties such as Golden Delicious, Worcester, and Crofton.

Another important maturation change which accompanies the softening of the flesh and the increase of juciness, is the conversion of the starch content of the fruit to sugar. A simple way to test the extent of starch conversion is to wet cut tissues with an iodine solution. A convenient solution can be prepared from 1 g. iodine, 4 g. potassium iodide, and 100 ml. water. This turns starch a purplish blue.

By cutting a series of apples from very immature to ripe transversely through the core and wetting the cut surfaces with the iodine solution certain facts become evident (Figs. 17-23), *provided the fruit tested is freshly picked.*

In very immature fruit all tissues will show a dense starch reaction. With more mature fruits two types of reaction will be found:

(1) In varieties like Yates (Fig. 19) which are not subject to tree or storage pit, the starch reaction becomes uniformly weaker in all tissues with increasing maturity. If anything, the starch tends to disappear first close under the skin.

(2) In varieties like Cleopatra (Figs. 20-22), Cox, and Granny Smith, which are subject to tree or storage pit, starch is not lost uniformly. The first starch-free areas appear in the core. The core is usually free or nearly so from starch before starch-free areas appear in the cortex. These starch-free areas in the cortex appear in a pattern which becomes more evident as they increase in size. The last tissues to lose their starch are found in association with the vasculars, particularly the larger ones radiating from the core line and the capillary network close to the skin. Finally all starch disappears. There is for a varying period a close association of starch-filled and starch-free areas. It is in this period that pit may develop. Each variety has its own type of starch loss pattern. The more complex patterns are usually associated with high pit susceptibility, while lower pit susceptibility accompanies less distinct patterns.

A similar series of apples cut longitudinally through the core shows the same delayed starch loss associated with the core line vasculars and the capillaries near the skin. It will be seen that starch disappears more rapidly in the stem than the calyx half of the fruit and last from the outer flesh of the latter.

The reason why fruit to be tested for starch should be freshly picked is that the conversion of starch to sugar occurs more rapidly and more uniformly in picked fruit. Very immature fruits picked and held for a few hot days may show little or no starch though still definitely immature in every other respect.

V. MEANING OF TERM "CROP SIZE"

The meanings of the terms "light, medium, or heavy crops" (Carne 1940) as used in this publication do not necessarily agree with their common usage. By light crops growers usually mean those which produce less than the normal number of bushels, and by heavy crops those which yield a greater than normal number of bushels.

As used here a light crop means one in which the average size of the fruit at the normal optimum harvesting time is greater than the normal size, and by a heavy crop an average fruit size less than normal. In this sense a heavy crop because of the small size of its fruit may give few or no more bushels than a lighter crop because of the large size of the fruit of the latter. In general, however, a light crop is light both on the basis of average fruit size and bushels produced.

Usually light and heavy crops are related to light and heavy fruit sets, but climatic conditions or loss of fruit by thinning or other causes may upset this relation. A light or subnormal setting given normal growth conditions will give fruit above normal size at harvest. However, drought may check the fruit growth resulting in a moderate or even heavy crop on the basis of fruit size. A good to heavy set will usually give normal to small sized fruit but unusual rainfall or irrigation may reduce the crop to light or medium size on the basis of fruit size, though still good to heavy in bushels. This has been noted mainly with heavy rains just before and during the normal harvest period, a very unfavourable event for the storage capacity of fruit.

There is for every variety an optimum average size of fruit at normal picking time which is the largest average size consistent with a reasonably low susceptibility to non-parasitic disorders. This average size is the "normal" average from normal crops. A normal crop consists of a range of sizes but the majority of fruit approximates the average size. In crops with above "normal" fruit size, the susceptibility to disorders rises sharply. Below the normal average size susceptibility declines, but much less sharply.

The normal size is determined by storage trials, but it is not accidental that for the commonly exported varieties it agrees closely with the preferred sizes for Australian apples in United Kingdom markets. This preference is undoubtedly the outcome of years of experience that on average the outturn and keeping quality of different varieties falls off markedly over a certain fruit size for each. The safe maximum average sizes which constitute "normal" crops at the optimum picking time include:

Normally small varieties ..	2¼ in. diameter ..	Cox.
	2⅜ in. diameter ..	Sturmer, Yates, Worcester, Crofton, Dougherty.
Medium sized varieties ..	2½ in. diameter ..	Jonathan, Cleopatra, Scarlet, Rokewood, Tasman Pride.
	2⅝ in. diameter ..	Rome Beauty, Delicious, London Pippin.
Normally large varieties ..	2¾ in. diameter ..	Granny Smith, French Crab, Democrat.

VI. FACTORS INFLUENCING THE SUSCEPTIBILITY OF APPLES TO NON-PARASITIC DISORDERS

There are many factors predisposing apples to physiogenic disorders and other mishaps. The more important are included in the following:

(*a*) *Varietal Characteristics*

Varieties differ greatly in their resistance to mechanical and chemical injury and their susceptibility to physiogenic disorders. In any variety such susceptibility is not constant but may vary with the size of the fruit and particularly with the size of the crop (Carne and Martin 1938*b*) from which it is taken, even when the maturity appears to be the same. There are variations due to seasonal climate and the manurial programme used, though these are closely linked with crop size. There may be striking differences between the fruit of different years from the same tree. It is even possible for the fruits from different parts of one tree to differ in their susceptibility.

It is probable that softness, in the sense of susceptibility to bruising rather than to penetrometer resistance, is related to the relative size of the flesh cells and the relative proportion of the fruit represented by intercellular air spaces. Thus Jonathan is a soft or light variety, Granny Smith harder, and Stone Pippin still harder and heavy. Penetrometer tests are a measure of the softening of similar apples in any given season. But light crop apples, though more subject to bruising, show higher penetrometer tests than heavy crop fruit of the same variety picked at the same time in the same orchard. The penetrometer test would appear to be largely a measure of combined cell turgidity and flesh density.

Some of the varietal factors affecting liability to physiogenic disorders include:

(i) *Irregular starch loss.*—High liability to tree and storage pit in Cox and Cleopatra is associated with very irregular starch loss patterns, whereas Yates, Dougherty, and Democrat have a very regular starch loss and low pit susceptibility (Carne *et al.* 1929).

(ii) *Titratable acidity.*—Varieties with high total acidity such as Cox, Sturmer, Scarlet, and French Crab are more susceptible to low temperature breakdown than those of low acidity. The latter include Worcester, Yates, Democrat, Dougherty, and Crofton.

In general, the low acid, mid-season to late varieties such as Democrat, Yates, Dougherty, Crofton, and Granny Smith are longer keeping than the earlier low acid varieties like Worcester and Dunns. Exceptions to the relation of acidity to keeping are Delicious, a low acid variety subject to early senescence, and Rokewood, a high acid apple of very good keeping capacity. Sturmer is a high acid variety which keeps well under conditions not favourable to low temperature breakdown.

(iii) *Specific gravity.*—Hard or heavy varieties are more subject to early watercore than soft light varieties which are more subject to late watercore. The former include Stone Pippin, French Crab, Democrat, and Rokewood, and the latter Jonathan, Gravenstein, Worcester, and Geeveston Fanny. Heavy varieties have generally a longer life before the onset of senescence than light varieties. Senescence is shown by loss of flavour, mealiness, and senescent breakdown of the flesh.

(iv) *Flavour.*—Apples of marked flavour are more subject to physiogenic disorders than those of little flavour. The former include Gravenstein, Cox, and Ribston, and the latter Worcester, Democrat, Yates, Statesman, and Dougherty. In general, high flavour and high acidity go together but Delicious and Legana (a Delicious cross) are exceptional in being low acid varieties of high flavour. In susceptibility to disorders they are intermediate, as are most varieties of medium acidity and flavour. Their characteristic flavour appears to be of different origin from that of other varieties.

(v) *Season of maturity.*—Early varieties have a shorter storage life than late varieties. Early high acid varieties are generally the most subject to physiogenic disorders and late low acid varieties the least.

(vi) *Skin waxing.*—Varieties like Granny Smith, French Crab, Stone Pippin, Ballarat, and Democrat, which develop a pronounced waxy bloom, generally have a longer storage life, without becoming mealy and flavourless, than those with little bloom such as Jonathan and Delicious. Varieties like Cleopatra and London Pippin which develop a strong bloom but have open cores are intermediate, as are those with an intermediate bloom and closed cores.

(*b*) *Size of Fruit and of Crop*

As between fruits of different sizes picked at the same time from one tree, the larger fruits are more subject to both mechanical injury and physiogenic disorders than smaller.

As between trees of the same variety grown under similar conditions, the fruits of light crops are more susceptible to both mechanical injury and physiogenic disorders than fruits of heavy crops, size for size and collectively, when picked at the same time. *This relation of crop size to non-parasitic disorders is second only in importance to the variety relationship; within a variety it is the most important factor* (Carne 1940).

Light crop fruit is always far less desirable for storage and export than heavy crop fruit because of its greater susceptibility to disorders.

The length of the optimum picking time is much shorter and maturity harder to determine in light than heavy crop fruit. Grown under similar conditions, light crop fruit in appearance and edibility matures earlier than heavy crop, but in relation to acidity and starch loss it matures later. Thus if picked late it has a high susceptibility to senescent breakdown and if picked at or before the optimum time for normal crops its susceptibility to storage pit is increased.

(*c*) *Maturity*

The primary susceptibility to most disorders determined by varietal and other factors varies with the maturity of the fruit. Susceptibility to tree and storage pit in liable fruit commences with the appearance of starch-free areas in the cortex, rises rapidly to a maximum, and declines with increasing maturity. Liability to early watercore commences in immature fruit and declines with maturity, while the reverse is true for late watercore. Fortunately most varieties are susceptible to only one of these two disorders. Liability to senescent breakdowns increases with maturity in all cases (Carne 1940).

As a consequence of the foregoing, buyers' colour preferences frequently influence the picking time and hence the liability of apples to storage pit, watercore, and senescent breakdowns. Those like Granny Smith and culinary varieties, in which the preference is for a green ground colour, are more likely to be picked immature than red varieties. Those preferred with a well developed red colour, such as Jonathan, are more likely to be picked late to obtain as much colour as possible. Hence, storage pit and early watercore are more likely to be found in green to yellow varieties and late watercore and senescent breakdowns in the red varieties.

(*d*) *Climate*

The primary susceptibility to disorders due to varietal and crop factors is in some cases increased or offset by climatic factors. Low temperatures during the three weeks or so preceding the normal harvest time increase the susceptibility to low temperature breakdown of liable varieties, whereas high temperatures decrease the susceptibility.

Climate also affects the incidence of some disorders as distinct from susceptibility. For instance, periods of heat and wind (heat waves) increase the onset of tree and storage pit, watercore, and crinkle (Carne and Martin 1934).

VII. CLASSIFICATION OF DISORDERS BY SYMPTOMS

Section 1. Poor Setting of Fruit

Poor setting of fruit may be due to many causes including:

(*a*) Excessive cropping in the previous season, resulting in poor fruit bud development and consequently few flowers.

(*b*) Unfavourable spring growth of the previous year followed by heavy growth in early and mid-summer which may result in the shooting of spring-formed fruit buds and the failure of late growth to mature buds properly.

(*c*) Lack of winter temperatures low enough to cause the trees to become properly dormant. This results in a long flowering season, and poor setting of frequently malformed fruit. If the spring conditions are very favourable for growth, spur growth is often terminated by flowers instead of fruit buds for next season.

(*d*) Thrips infestation, hot winds, or frosts, damaging the floral organs and resulting in non-setting or malformed fruit.

(*e*) Lack of effective cross-pollinating varieties suitably placed.

(*f*) Cold wet weather at flowering time keeping bees from working.

(*g*) Excessive soil moisture in winter and spring resulting in root injury and subsequent flower injury.

Section 2. Premature Fruit Fall

It is natural for an apple to fall as it approaches or attains ripeness on the tree. For this purpose a corky abscission layer develops across the base of the stalk. When complete this layer severs the vascular and living tissue connexion with the tree. The layer is easily broken and the fruit falls of its own weight or when shaken. The abscission layer forms more readily and rapidly in early than in late varieties which hang much longer on the tree after becoming ripe.

The causes of premature fruit fall are either the premature development of the abscission layer or mechanical breaking of the stalks from the tree or of the stalks from the fruit. They may be conveniently grouped according to whether they involve small non-commercial fruits or well-grown fruits approaching picking maturity.

(a) Falling of Small Non-commercial Fruits

(i) *Defective seed development.*—This is the main cause of the natural thinning of the small fruits set in the spring (October and November), which prevents an accurate estimate of the probable crop much before the end of December. Failure to set the seeds which are normally essential for an apple to grow to maturity may be due to:

(1) Lack of pollen from suitable varieties in the case of self-sterile varieties.

(2) Weak or otherwise defective pollen of suitable varieties.

(3) Weak or defective ovule-bearing organs.

(ii) *Starvation.*—The young fruits may fail to develop normally through defective nutrition. This occurs mainly on weak spurs, usually individual spurs, though such a condition may be general on a tree. In the latter case it is not uncommon for the flowers to set freely and for most of the young fruit to fall later. In a light crop following a heavy one, the weaker spurs frequently fail to hold their fruits. This is not so in a light crop due to frost or thrips infestation.

A special form of starvation occurs on boron-deficient soils, especially when the soil is lacking moisture in the spring. Many of the young fruits develop superficial cork and subsequently fall (Section 32).

(iii) *Frost.*—Frosts on young fruits may cause either or both injury and fruit fall. In the latter case the developing seeds have been killed (Section 27).

(iv) *Sprays.*—Spraying in or just before very hot weather, especially with strong solutions, of trees suffering from lack of moisture may cause a heavy fruit fall. The danger is greatest with sprays containing oil or sulphur.

(b) Falling of Maturing Fruits

(v) *Drought conditions.*—Dry hot conditions tend to hasten the development of the abscission layer. Windfalls are likely when the trees are suffering from lack of moisture due to either soil dryness or root injury. The hot dry winds of January to March tend to shake off fruits of varieties which mature early owing of the weakening effect of the developing abscission layer. Gravenstein, Williams' Favourite, Ribston, Alexander, and, of the more important varieties, Jonathan, are subject to heavy windfall. This can be effectively prevented in sound fruit by hormone spraying (usually with naphthaleneacetic acid), provided clustered varieties have been sufficiently thinned.

(vi) *Cluster pressure.*—Short-stalked varieties such as Jonathan and Yates are apt to set in clusters of four or more fruits. As the clustered fruits grow they become short of room, and as a result of the pressure one or more are pushed off by breaking the stalk, by pulling the stalk out of the fruit, or by rupturing the developing abscission layer. With more room the lateral pressure on the remaining fruits may result in sufficient movement to rupture the abscission layers and so cause more fruits to fall. This also happens when a fruit is picked from a tightly packed cluster.

Early thinning to singles or doubles prevents the pressure arising and permits effective use of hormones to delay the abscission layer formation. It also increases the effectiveness of spraying for insects and fungi.

(vii) *Premature ripeness.*—Premature ripeness follows internal injuries caused by boring insects (such as codling moth) and natural ruptures (such as severe split core and mouldy core). Premature ripening is accompanied by premature development of the abscission layer in the stalk, with fruit fall as a consequence. Up to a point this is useful as a natural separation of sound and unsound fruit, but it is rarely complete at the normal picking time. Premature ripeness appears to be associated with access of air to the internal tissues of the fruit rather than directly to injuries.

Section 3. Malformed and Asymmetrical Fruits

Within a run of apples of any variety there is a recognizable typical shape, though a proportion of atypical fruits will always be found. The average shape will vary to some extent according to the vigor of the trees, and the climatic conditions, mainly in the relation of length to diameter. Vigorous trees and cool climates tend to produce more elongated fruits than weaker trees and warmer climates. Malformation may occasionally occur through mechanical pressure, as when a fruit is caught in a branch fork and is unable to grow normally.

The following are the most common causes of asymmetrical growth or malformation:

(*a*) *Defective Pollination.*—Failure to set seed in all the five carpels may lead to asymmetrical growth. The sectors with seed tend to grow more strongly than those without. Failure to set seed may be due to self-sterility, absence of bees, lack of suitable pollinating varieties, or injury to the stigmas. Such injury may be caused by frost (Section 27), thrips infestation, dry winds (Section 25). Malformed fruits may result from spray treatments designed to reduce or prevent setting.

(*b*) *Rapid Growth of Open-cored Varieties.*—Apple varieties such as Cleopatra and Delicious have open cores caused by the separation of the carpels or seed cells at their inner edges. When the fruits make steady growth they are usually symmetrical. If, however, growth is alternately slow and fast, as when heavy rain follows dry conditions, internal ruptures occur frequently, followed by irregular development of the calyx end of the fruit (Section 7). This is most frequent in the central fruits of clusters. These are known as " buck " or " king " fruits and are characterized by thicker and often shorter stalks than those of lateral fruits in the same clusters.

(*c*) *Frost Injury* (Section 27).—Frost may cause an abnormal flattening or lobing of the calyx ends of fruit, or a depressed russeted ring around the calyx end called frost band.

(*d*) *Watercore* (Section 11).—Severe watercore, especially after heat waves, may be followed by irregular depressions (called crinkle), often to one side, and especially on the calyx half. Brown lesions occur immediately beneath the depressions.

(*e*) *Boron Deficiency* (Section 32.)—Very irregular surface depressions with mainly deep-seated brown lesions in the flesh.

(*f*) *Deep Scald, a Cool Storage Injury* (Section 19).—Smooth, sunken, sharply defined, dark areas usually on the calyx half and more or less around the fruit may develop at storage temperatures above the freezing point of apples but below about 36°F.

(*g*) *Dimples* (Section 16).—These are surface depressions, without internal lesions, the causes of which are still unknown.

Section 4. Persistent Chlorophyll

The failure of apples to change from green to yellow with time may be due to:

(*a*) *Frost Injury* (Section 27).—One effect of frost injury, noted in Sturmer in Tasmania, is to delay or inhibit the change from green to yellow at the calyx end. This leads to a striking colour contrast as the fruit matures.

(*b*) *Cork* (Section 32).—The surface blister-like lesions of cork (Figs. 54, 57) are characterized by the persistence of chlorophyll around dead tissue. The overlying skin, before the surface is sloughed off, may be green or show a green border even on red surfaces. Beneath the skin the brown lesions often show a green surrounding zone.

(*c*) *Abnormal Colouring of Immature Fruits.*—Very immature fruits wilt quickly when picked and do not ripen normally, the flesh becoming leathery and dry and lacking flavour and sweetness. The ground colour may remain green or turn yellowish with the green persisting in the stem and calyx basins.

(*d*) *Blotchy Form of Tree Pit* (Section 14).—The large surface pits (Fig. 30) are usually first dark green then dark green mottled with brown and finally brown. If picked immature the green colour may persist at the pits, the fruits otherwise becoming yellow.

(*e*) *Skin Treatments* (Section 31).—Treatments of wax and oil emulsions or castor oil and shellac, designed to check ripening and loss of moisture, usually delay the changes from green to yellow. In immature fruit, especially, the change may be prevented entirely and the fruits remain green.

(*f*) *Gas Storage.*—Storage in atmospheres higher in carbon dioxide and lower in oxygen than ordinary air delays the ripening and yellowing of apples. This is a desired objective and cannot be regarded as a defect.

Section 5. Wilt

Wilting is indicated by a general dullness in the appearance of fruit accompanied by a tendency of the skin to wrinkle under lateral pressure of the fingers. The flesh lacks juice and is flaccid or mealy. In severe cases the skin is visibly wrinkled (Fig. 3).

The following forms are recognized:

(*a*) *Fruits on Trees*

Immature fruits may be wilted following severe drought conditions, heat waves, or when exposed to abnormal heat as from nearby bush fires. It may also result from root injury such as is caused by waterlogging of the soil and other causes (Carne *et al.* 1931).

(*b*) *Picked Fruit*

(i) Fruits picked when immature wilt readily if held at too high temperature or in conditions of excessive air movement, or both, or if stored too long. The flesh is flaccid and lacks flavour. Immature fruit does not develop a waxy bloom.

(ii) Fruit picked when mature wilts if held too long in storage or under unsatisfactory storage conditions. The flesh is more or less mealy and lacks flavour. Varieties which develop a definite waxy bloom as they mature are less subject to wilt than those with less bloom.

(iii) Fruits with injured (but not broken) skins tend to wilt under and around the injured parts. This is particularly noticeable when spray-burned or sunburned fruits are held in storage. The flesh of the wilted portions tends to be flaccid, but is of good flavour in mature fruits.

The production of an artificial bloom by treating wilt-liable varieties with a wax emulsion is effective in checking wilting, provided they are not of the open calyx-tube types (Delicious, Cleopatra, &c.). Such treatments must be used with care because, unless properly handled, they may cause lenticel spotting of the fruit or scald. High atmospheric humidities in the store, including those associated with gas storage, reduce wilting.

Section 6. Russet and Russet-like Markings

Natural russet is a brown, minutely cracked and roughened condition of the skin. It is caused by the death of the cuticle or outer layers of the epidermis. A brown protective layer of cork cells forms beneath the injured surface.

Russet is characteristic of certain varieties and tends to be more developed in cool moist than in warm dry climates. The skin of the stem basin and the stem half of the fruit is always more likely to be affected than the calyx half. Varieties which produce a fruit characteristically russeted all over are now rarely grown in Australia, but some varieties, notably Cox, Ribston, and Newtown, usually show some degree of stem-end russet. Dunns is very subject to stem-end russet, but this is exceptional in that it is more severe in warmer climates. Why this is so is unknown.

Other brown injuries of the cuticle and epidermis may be caused by insecticidal and fungicidal sprays and even by fungi. Some may be distinguished by the absence of the minute cracking but it is frequently difficult to distinguish others from natural russet.

Sometimes the growth of fruit subsequent to russeting results in severe cracking which may extend deeply into the flesh. Such fruit is not suitable for shipment or land cool storage as the moist atmospheres encourage the development of fungal rots in the cracks. The main objection to russet free from severe cracks is its effect on appearance. While it is common both in Australia and the United Kingdom to hear people praising the flavour of Russet varieties and regretting their disappearance, the market demand is very definitely in favour of smooth bright fruit and this is the reason that Russets are no longer grown commercially. The flesh beneath the russeted surface of an apple, though it tends to wilt earlier than under smooth skin, certainly appears to retain its flavour better.

Several types of russet are described below:

(a) Natural Russet

Natural russet, covering the whole or the greater part of the surface, is characteristic of " Russet " varieties. Some varieties have a strong tendency to become russeted at the stem end. When very marked stem-end russet is a defect.

(i) *Normal stem-end russet.*—This is recognized as a defect when it extends beyond the stem basin and especially when it is rough, ugly, and accompanied by deep cracks. Varieties subject to this stem-end russet include Cox, Ribston, Newtown, and Sturmer.

(ii) *Stem-end russet and crack of Dunns.*—This variety which normally carries a little russet at the stem end is occasionally very liable to a severe rough russeting covering up to one half or more of the surface. Unlike normal stem-end russet, this form occurs mainly in the warm dry climates in the eastern States and Western Australia and not in the cooler climate of Tasmania. Severe occurrence is more frequent in light crops and large fruit but seasonal factors, not yet understood, are of more importance than crop or fruit size. Severe cracking often accompanies severe russeting of this type.

(b) Smooth Russet (so-called) on Red Apples

This is not a true russet and is more associated with the destruction of the red pigment layer of the skin than with the death and minute cracking of skin tissues. It appears as irregular areas or streaks of light-brown colour in the otherwise red areas. Its cause is not known but is distinctly seasonal. It may affect the appearance of red apples unfavourably as in Jonathan and Scarlet. Lime sulphur sprays may increase the trouble but are not the primary cause.

(c) Mildew Russet (so-called)

This is a smooth brown marking of the skin associated with injury to the cuticle caused by the apple mildew fungus though the minute cracking of typical russet is absent. It ranges from a very slight brownish discolouration to a darker staining. It is rarely of economic inportance.

(*d*) *Spray Staining, Russet, and Burn* (Section 31)

These are different degrees of injury to the skin caused by sprays, particularly of copper preparations such as Bordeaux mixture (Fig. 5). This injury ranges from stains, through normal russets, to a severe and deep russeting accompanied by rough irregularities of the surface known as spray-burn. Sturmer and many other varieties may be affected.

(*e*) *Superficial Cork or Drought Spot Russet* (Section 32)

This is a russet-like skin injury developed on young fruits in the first few weeks after setting (Fig. 53). It is a symptom of boron deficiency.

(*f*) *Frost or Ring Russet* (Section 27)

This russet (Fig. 4) is characterized by its occurrence mainly on the calyx half of the fruit but not in the calyx basin. It is developed early in the life of the fruit and is followed by some restriction of growth.

(*g*) *Blisters or Scabs, Warts, and Russeted Depressions*

(i) *Blisters or scabs* (Section 8), refer to lesions in which the dead skin is more or less sloughed off leaving brown corky tissue exposed. Part of the dead skin remains on or around the lesions.

(ii) *Warts* (Section 8) mean raised russeted growths on which the russet is later more or less replaced by a new smooth brown skin.

(iii) *Russet in depressions.*—Scratches, insect punctures, frost and other causes still not identified, operating early in the life of an apple may result in russeted depressions and dimples. Dimples (Section 16) show a very small russeted patch at the base (Fig. 31).

Section 7. Open, Hollow, Split, and Mouldy Core

All these disorders are different degrees or consequences of "open core", therefore the same varieties are subject to all.

(*a*) *Open Core* is the term used for a condition in which the calyx tube of certain varieties opens directly into the core cavity (Bell 1940). Through this open connexion the spores of saprophytic fungi may gain access to the core cavity. Open core is characteristic of Cleopatra, Delicious, Gravenstein, and London Pippin, especially when large. Other varieties may show the condition to a limited extent.

(*b*) *Hollow Core* is a condition in which growth stresses have separated the horny endocarps or carpels from the central attachment and opened them out to form a central cavity. Frequently the endocarps have their internal surfaces ruptured transversely and the cracks filled with white spongy cells. This is known as "woolly stripe". The spongy cells eventually turn brown as the fruit ripens. Fungal mycelium (filamentous growth) is not uncommon in hollow cores but it is unable to attack the flesh of the apple through either the endocarp or the woolly stripes. Its only consequence is a brown discolouration of the inside of the carpels.

It is characteristic of open-cored varieties that some degree of hollow core is always present, the cavity usually increasing with the size of the fruit.

(*c*) *Split Core* (Carne *et al.* 1930) is a development from hollow core in which the endocarps are ruptured at their outer angles and especially towards the calyx end of the fruit. These ruptures extend into the flesh, in bad cases almost to the skin (Fig. 8).

Split core occurs mainly in the larger fruits of open-cored varieties of light crops and in " king " apples. King apples are the central fruits of clusters and can be recognized by their shape being rather different to the lateral fruits, and by their shorter thicker stems. If the splitting occurs while it is still growing rapidly the fruit is often malformed. This malformation is usually a longitudinal flattening or a lobing of the fruit at the calyx end. Deep depressions, when present, overlie the internal cracks. Provided they are not previously attacked by fungi the internal cracks become covered with a dry brown corky tissue which protects them from infection. Such browned tissue is very common in Cleopatra at the base of the calyx tube but unless extensive is a very minor defect.

If fungi attack the ruptured flesh before it becomes dry and brown the condition known as mouldy core results.

(*d*) *Mouldy Core* (Carne *et al.* 1930) usually refers to the condition of fungal rotting set up in apples with split core by fungi which have gained access to the core through the open calyx tube (Fig. 8). The rots develop slowly and apparently sound fruits may be packed and marketed. On cutting, such fruits prove to be rotten inside. In time the rots extend to the surface.

There are two other forms of mouldy core. One may follow on the dipping of open-cored fruit in acid baths for the removal of arsenical spray residues. If the fruit is dipped too deeply or too long the acid solution may enter the calyx tube and core and kill the tissues around them. The injured tissues become very liable to fungal infection. In such cases it is not uncommon for the rot to extend right through the fruit to the stem end.

The third form may develop following the penetration of the fruit to the core by codling moth larvae, especially when their entrance is down the calyx tube. The insect workings give fungi access to the flesh.

(*e*) *General.*—One effect of split core is to hasten ripening by allowing freer access of the air to the flesh than in normal fruits. Insect workings have the same ripening effect.

The treatment of apples with waxes, oils, and castor oil shellac solutions to slow up ripening and yellowing is not effective with open-cored fruit because such treatments act by restricting air movement through the skin. They do not stop air movement through the calyx tube. Further, they are apt to cause calyx tube injury with subsequent calyx rots. This is particularly true of wax emulsions.

Liability to split and mouldy core is greatest in large fruit from light crops. Both are likely to be increased if the fruit makes rapid growth when rain follows drought conditions.

(*f*) *Control.*—If thinning of susceptible varieties is practised, the large " king " apples in the centre of the clusters should be removed. Fruit with malformed calyx ends or flattened or grooved longitudinally should not be stored or packed for shipment.

Section 8. Cracks, Blisters, and Warts

Cracks are skin ruptures which extend into the flesh. They are generally due to the inability of the superficial tissues to accommodate themselves to the growth of the fruit.

Blisters refer to dead skin which becomes loosened and may be sloughed off exposing brown corky tissue beneath. This death and contraction of the skin is usually confined to the stem or calyx basins late in the growth of the fruit. Cork blisters (Section 32) are an exception.

Warts are raised lumps on the fruit surface which are brown and usually more or less russeted. They are responses of the fruit to surface injuries early in its growth.

(*a*) *Fruit Cracks*

(i) *Frost cracks* (Section 27).—These have their origin as the result of frost affecting recently set fruit. The cracking usually runs parallel to the axis of the fruit and is associated with the vasculars of the core (Figs. 6, 7). Lateral cracks may develop from the primary cracks. Later in the life of the fruit the cracks may be found as elongated depressions with brown corky tissue at the base.

(ii) *Sunburn and russet cracks* (Section 6).—Severely russeted or sunburned fruits tend to crack with growth owing to the inability of the affected surface to grow normally.

(1) *Stem-end cracks.*—Normal russet always tends to have its greatest development in and around the stem basin. In the large fruits of light crops of varieties such as Cox and Dunns, which are subject to stem-end russet, stem-end cracks are not uncommon. They tend to develop around the basin.

(2) *Lateral cracks.*—Sunburn, frost, and boron deficiency, or other causes of russet-like death of the skin may result in irregular or stellate cracks on the cheeks of fruits.

(iii) *Calyx-end cracks.*—This is relatively uncommon and mainly results from frost, spray, or chemical injury killing the surface tissues. Rarely it occurs when drought-affected fruits make rapid growth after rain or irrigation.

(iv) *Stem-insertion cracks.*—This refers to minute ruptures immediately around the stem at its point of entering the fruit. They are due to the shrinkage of the stem. Fruit picked too late is subject to this injury and a subsequent liability to stem-end rots. Natural healing in mature fruit is slow and rot liability high. Susceptibility to stem-end rotting limits the lateness of picking for storage of some varieties otherwise very free from storage disorders. These include Democrat, Worcester, Yates.

(v) *Apple scab cracks.*—Apples badly affected by the scab or black spot fungus (*Venturia inaequalis*) may crack badly as they grow.

(vi) *Breakdown crack* (Section 19).—Over-mature apples affected with senescent breakdown in cool storage may become cracked, the skin turning back and exposing the mealy flesh (Fig. 29).

Cracks spoil the appearance and lower the grade of fruit. If the exposed tissues escape infection by rot fungi before they become healed with corky tissue, the fruit will stand any ordinary handling without rotting. In cool storage, or more frequently during the period the fruit is wet by condensation after cool storage, even the apparently healed cracks become liable to infection especially at their edges. Fruits with disfiguring or unhealed cracks should be treated as culls and discarded.

(*b*) *Blisters*

(i) *Stem-end blister (or dry stem ring)*.—In this the skin on the stem cavity dies and lifts as a brown blister (Fig. 9). It tends to break away forming a dry collar around the stem. The tissues underneath develop a protective cork.

This disorder does not appear to be serious though at first sight it would suggest liability to stem rots. It occurs mainly in the later varieties such as Yates, Dougherty, Rokewood, and Democrat which usually mature during the cool moist weather of late autumn. It has, however, been noted in Jonathan, Statesman, Rome Beauty, and Granny Smith when droughty conditions have been followed by rain. It is suggested that water collecting in the stem basin may be associated with the cause of this trouble.

(ii) *Calyx blister*.—This is less common than stem-end blister and the lifting of the dead skin is less marked. The cause is uncertain but is probably associated with rain following drought as in stem-end blister. It can be confused with calyx-end frost injury (Section 27). It has been noted in Dougherty, Jonathan, Granny Smith, Rokewood, and Yates. In one instance it was associated with blocked drainage, and clearing the drains proved an effective prevention. The calyx tube may be ruptured and the fruits may occasionally develop rots under humid storage conditions.

(iii) *Cork blister* (Section 32).—One form of boron deficiency disorder is the occurrence of raised lumps (Figs. 54, 55) usually at the base of surface depressions. The skin on these lumps dies and eventually sloughs off exposing brown corky tissue beneath.

(*c*) *Warts and Brown Grooves* (Section 17)

Warts are patches of brown more or less russeted skin raised above the surface of the apple. There is no brown corky tissue beneath. They are a growth response to injury caused to young rapidly growing fruit, particularly those caused by the bites of insects of the grasshopper or tree locust type. Later injuries of a similar nature, though turning brown, tend to remain at or below the general surface level of the fruit forming grooves and depressions.

Section 9. Bruises, Cuts, and Abrasions

(*a*) *Bruises at Temperatures above the Freezing Point of Apples*

Bruises are due to rough handling (Section 24). Liability increases with the maturity of the fruit. Fruit which has grown quickly is full of moisture and bruises more readily than slower grown fruit. Large fruit bruises more readily than small. Varieties vary considerably in bruise liability. Soft varieties and those of irregular shape are the most liable.

(i) *Recent bruises.*—These may be recognized by flattened or depressed areas on fruit with a dark water-soaked appearance especially in yellow-skinned varieties. Internally the injured flesh is moist and rapidly becomes dark in colour. The affected areas may be somewhat convex (Fig. 19) on their inner limits, but are usually roughly parallel to the surface. The degree of convexity depends upon the nature of bruising, i.e. whether caused by box boards, adjoining fruit, &c.

(ii) *Old bruises.*—These show little or no surface discolouration though the depressions or flattened areas remain on the surface. The internal lesions are brown, dry and spongy, and shallower and lighter in colour than in (i), and roughly parallel to the surface. A line of rupture with open cavities is frequently found between the sound and injured flesh due to the shrinking of the latter.

In some varieties, notably Sturmer, fresh bruises are very evident on the fruit. Later the surface appearance returns to normal though the dry brown bruised tissue can be found on cutting.

(*b*) *Bruises at Temperatures below the Freezing Point of Apples*

Apples freeze at temperatures below about 29°F. They then become very subject to bruising. Jars which would not affect apples of normal maturity at ordinary temperatures may then cause severe bruising. This can be distinguished from normal bruising in that it is more water-soaked, lighter in colour, and extends inward to greater depths. Instead of the injured tissue being roughly parallel to the fruit surface it tends to form a cone with its apex at or near the core line.

(*c*) *Box Cuts and Rubs*

These are due to handling factors including careless packing and lidding, badly made or warped boxes, rough box wood, and insufficient protection by paper wraps, strawboards, anti-friction liners, &c. Packing too high at the ends of cases often leads to abrasion of the end fruits during lidding of bulged packs.

(*d*) *Nail Injuries*

These are due to projecting nail points, a result of careless nailing especially when lidding.

(*e*) *Stem Punctures and Bruises*

These are small bruises or punctures caused by the pressure of the ends of stalks against the fruit. There are two major causes in packed fruit:

(i) Pressure of a stalk of one fruit against the skin of another. This occurs most frequently when diagonal or crisscross packs are used. Least trouble is caused in straight packs, i.e. packs in which the fruit lies along the main axis of the box, the stem-end lying between two fruits in the previous cross row.

(ii) Pressure of the stalks of long stalked varieties against the fruits to which they are attached. This often occurs in wrapped fruit when the stem is pressed against the fruit instead of being caught in the twist of the wrap.

(*f*) *Grader Marks*

These are usually small but often numerous bruises, scratches, and abrasions caused by careless tipping of fruit on to grading tables and insufficient attention to cleanliness and roller adjustment in the sizing equipment. Dirt, especially when mature fruit has developed its natural greasiness, often collects as small knobs on belts and rollers against which the fruit is bruised. Wear and tear often leads to projecting pieces of metal or wood which may bruise or puncture the fruit. Defective operation especially in relation to the speed of belts and rollers may cause considerable bumping and bruising of fruit of irregular shapes such as Delicious, London Pippin, and Sturmer.

(*g*) *Wind Bruises, Scratches, and Cuts* (Section 25)

These occur when the movement of fruit on the tree by wind causes them to bump or rub against projections, branches, props, &c. Curious markings have been observed in long stemmed varieties such as Granny Smith and Golden Delicious following strong wind storms and whirlwinds. These caused circular and figure eight markings as the fruit was swung against spurs and stubs.

(*h*) *Hail Bruises, Cuts, &c.* (Section 26)

Hail injury varies from small pit-like bruises to extensive irregular cuts and gouging of the flesh. The injury varies with the size of the hail stones and the force of the accompanying wind.

General

Skin ruptures on immature fruit heal rapidly, but as the fruit ripens healing is slower and the injuries may be invaded by rot fungi before it is effective. This is especially true in humid storage atmospheres.

Section 10. Undesirable Skin Deposits

(*a*) *Arsenical Residues*

Arsenical residues from spray treatments for codling moth and other biting insects are objectionable because of their possible danger to health, if eaten, as well as being unsightly. No danger is involved if the arsenic calculated as arsenic trioxide does not exceed the permitted tolerance of 0·01 grain per lb. of fruit, even if the skin is eaten. To prevent undue accumulation of arsenic on the fruit in districts where the prevalence of codling moth makes frequent spraying or dusting essential, white oil is now often used for the late sprays instead of arsenicals. It should not be used on fruit already carrying a heavy arsenical load as it makes the removal of the latter more difficult. The use of acid dips to remove arsenic is expensive and has other drawbacks (Section 31). They are rarely used in Australia. Preference is given to spray schedules which do not leave excess arsenic. Arsenical dusting of apples is rare in Australia.

(*b*) *DDT Residues*

There is a tendency for DDT spray to replace arsenicals wholly or partly in the control of codling moth &c. A tolerance of 10 part per million or 0·007 grain per lb. of fruit is regarded as safe for eating. The residues are not unsightly.

(*c*) *Other Spray Residues*

Other spray residues, such as of fungicides used to control late infections of the scab fungus, are of importance only if they affect the appearance of fruit or may be mistaken for arsenical residues.

(*d*) *Insect Excreta, Honey-dew, and Sooty Mould*

The problem of insect excreta is mainly confined to the serious occurrence of the apple leaf hopper, jassid, or canary fly (*Typhlocyba australis*) and especially in dry weather. The faecal specks are not only unsightly but are accompanied by the sticky excreta known as honey-dew, which collects dust and makes the fruit gritty and unattractive in appearance. Heavy rain removes the trouble at least temporarily until the insects are destroyed or disappear. Honey-dew is also excreted by woolly aphis (*Eriosoma lanigerum*) with similar effects. The black sooty mould fungus grows on honey-dew and makes the fruit dirty and unsightly.

(*e*) *Dust*

Dusty fruit is dull and unattractive in appearance and requires washing before eating. It is more objectionable if its adherence is increased by insect honey-dew and excreta or the natural waxy bloom of matured fruit. Varieties which form a heavy waxy covering such as Cleopatra and French Crab must be firmly rubbed to remove the dust from mature fruit. A light rub is sufficient with less mature fruit of these varieties, and mature fruits of less waxy varieties such as Jonathan and Yates. Dust should be avoided by keeping picked apples awaiting packing in a clean place protected from dust. Roads around the storage and packing places should be watered in dry weather and dry sweeping of floors should be avoided.

Picked fruit stored outside in picking boxes should be stacked in the least dusty place available and protected by coverings.

Section 11. Watercore or Glassiness

This disorder is recognizable as a glassy translucent condition of the flesh of apples not necessarily in the core region as the name might imply. The affected flesh is more flexible and less crisp than that of normal apples. It is also sweeter and the juice more sticky. Though not unpleasant to eat it may have a slightly alcoholic flavour.

Watercore has its origin (Carne *et al.* 1931) in abnormal sap pressures in the cells which overcome the resistance of the cell walls and cytoplasm to the free passage of moisture. The sweet sap escapes into the intercellular spaces flooding the tissues, replacing the air, and thus destroying the normal whitish appearance of the flesh. It may even find its way through the skin to form sticky drops on the surface. Watercore normally originates in and around the main vascular tissues but may extend well beyond them. Exceptions occur in surface and possibly some forms of speckled watercore.

There are two main types of watercore, one originating in immature apples and the other associated with maturity. The term watercore is not appropriate in the latter case as the core, within the vascular ring, is not affected. It is, however, generally used in Australia.

(*a*) *Early or Immaturity Watercore* (Carne and Martin 1934)

This type originates in immature fruits during the warmer months, December to March, one to several months before the normal picking time of the variety though it may not be noted until then. As the affected flesh tends either to recover later or to die, the original symptoms may be lost or found only in residual form at picking time. The disappearance of watercore occurs more rapidly at higher than lower temperatures, and more rapidly after picking than on the tree. Within limits the more rapidly it is lost, the more likely is it that affected fruit will recover its normal storage capacity. However, the temperature must not be high enough to cause injury to the flesh before the watercore disappears. Because the disorder may not be detected until harvest time, its late persistence may lead to confusion with late watercore.

(i) *Major factors associated with early watercore*

(1) *Varietal susceptibility.*—Susceptible varieties include such hard good keeping kinds as Stone Pippin, French Crab, and Rokewood, especially in light crop years.

(2) *Crop size.*—Many varieties carrying only a light crop may be affected, especially following heat waves. These include Rome Beauty, Ribston, London Pippin, Democrat, Delicious, Dunns, Alfriston, Jonathan, Sturmer, King David, Ballarat, Granny Smith, Cox. The larger fruits are the more susceptible. High soluble solids content of the sap appears to be a weak feature of light crop fruit.

(3) *Heat.*—Dry hot weather, and especially a heat wave, is a major cause of watercore. The effect appears to be associated with temperature contrasts more than with the actual degree of heat. A sudden rise to 90°F. from a previous average of 70°F. is as likely to cause trouble as one from 80° to 100°F. Steadily rising temperatures are relatively unimportant.

Watercore may be induced in apples by directing heat on to susceptible fruit (Fisher *et al.* 1931). Heat affects exposed fruit and their exposed portions more than sheltered fruit. Defoliation by insects, disease or drought may increase liability by increasing the exposure of fruit. Sheltered low-hung fruit may be affected by heat radiation from light coloured soils. Previously shaded fruit may become exposed by the bending of branches under an increasing weight of fruit or by the hot dry winds which usually accompany heat waves.

The effect of heat appears to be an upsetting of normal starch deposition in the tissues. A rapid and premature hydrolysis of starch to sugar takes place. This is followed by a rapid movement of sap from the vasculars to the adjacent cells which develop high internal pressures and finally guttate sap into the intercellular spaces. The extent to which the tissues are affected is increased if ample soil moisture is present, during or immediately following the heat wave.

When in light crop even the rarely affected varieties Worcester, Yates, Dougherty, and Cleopatra may be affected during severe heat waves.

(ii) *Types of early watercore*

(1) *True watercore* (Figs. 23, 24).—This originates in and around the main vascular tissues of the core line especially towards the calyx end of the fruit. From the core line it extends into the core and outward into the flesh. It forms defined continuous areas of injected flesh which may extend to and involve the skin. Though the calyx end and the side exposed to the sunlight are the most liable, the greater part of a fruit may be affected.

Badly affected fruits can often be recognized by one or more of the following symptoms: dark water-soaked areas especially on green surfaces, a darkening and high polish of red surfaces, partial translucency of fruit when held to the light or candled like eggs, a sticky surface, and a weight greater than that of sound fruit of the same size. Failing these indications cutting the fruit is the only means of certain diagnosis.

It is to be expected in light crops of susceptible varieties, especially in the larger fruits and those most exposed to sunlight. Under heat wave conditions it may be found in normal crops of such varieties, and in light crops of many varieties. A prolonged heat wave or a following heat wave may result in the death of the water-soaked tissues causing sunburn (Fig. 26), crinkle (Figs. 23-25), or breakdown. This is most probably a consequence of inability of air to penetrate the flooded tissues, with anaerobic respiration and finally death as a result.

If the tissues escape death they tend to recover while the fruit is still on the tree, but careful examination will often enable previously affected flesh to be recognized by slight departures from normal colour and texture. Recovery on the tree is delayed by a humid atmosphere. If affected fruit of good keeping varieties is picked and held at moderate temperatures (60°-70°F.) it tends to recover rapidly and may then have a storage life approaching that of sound fruit. If placed directly into cool storage recovery is slower and the storage life may be reduced by the onset of breakdown (Kemp and Beare 1939). Varieties with a shorter storage life are more affected.

(2) *Speckled watercore.*—In this form the watercore appears as small patches in the cortex, especially in the outer cortex. It is often associated with watercore around the core line vasculars and the main branches into the flesh, but with little or none within the core. This form may be developed in fruit of a more advanced but still immature stage than true watercore, but usually it is only a residual form of it from which the fruits have partially recovered.

(3) *Surface watercore.*—This rare form has been seen only after extreme heat waves as when the shade temperatures have exceeded 110°. It was immediately followed by an unusual form of crinkle. The injected (flooded) tissue formed a shallow layer, not exceeding 0·5 cm., just beneath the skin. This extended over a large or greater part of the affected apples. It has been recorded only in Yates and Dunns.

(iii) *General observations*

Little can be done to prevent watercore in light crops, especially when heat waves are severe. To secure the maximum number of fruits on the trees and to keep down their size and susceptibility, light pruning and a minimum of cultivation, irrigation, and especially of nitrogenous fertilizers consistent with healthy trees should be used. Affected crops of varieties like Delicious should be marketed from the orchard. Good keeping varieties like Rokewood, Democrat, and Granny Smith should be picked during the normal season and held for about two weeks at ordinary temperatures to enable the watercore largely or entirely to disappear. They can then be placed in cool store.

(*b*) *Late, Radial, or Maturity Watercore* (Carne and Martin 1934)

This is developed in ripening fruit. The core centre is not generally involved or only slightly at the calyx end. The core line area and its branches into the cortex are mainly affected. In median cross sections of the fruit the affected areas in the cortex appear as narrow strips (Fig. 10) radiating from the core line like the spokes of a wheel. There are ten of these main cortex vasculars and any number may have watercore. If only a few are affected they are found on the exposed side of the fruit. Isolated patches in the cortex as in the speckled form of early watercore may occur.

Radial watercore occurs only in the softer early and early midseason varieties such as Gravenstein, Jonathan, Cox, Ribston, Tasman's Pride, Delicious, and King David. It may develop in normal crop fruit left to become ripe on the tree. However, it occurs earlier in light crop fruit.

Fruit with radial watercore will rapidly develop breakdown at ordinary temperatures. Cool storage delays the onset but the fruit never recovers its storage capacity. If it does not develop breakdown in cool storage it is liable to do so rapidly when removed to ordinary temperatures. Fruit affected with radial watercore should be marketed for early consumption.

Susceptible varieties should be watched and some of the larger fruit from lightly cropped trees cut as the picking season approaches. When the first evidence of radial watercore is found, the light crop trees should be harvested at once. If cool-stored they should be the first removed for marketing. Trees with good to heavy crops can be picked later and their fruit used for long storage. If all trees are light, the fruit should be carefully watched in cool storage.

Because light crop fruit is liable to pit and lenticel blotch if picked too soon and to watercore, breakdown, &c., if picked too late, some deterioration in cool storage is almost certain unless the fruit is marketed shortly after picking. To secure the best keeping of such fruit it is desirable not to pick it before the first signs of watercore are found or before the middle of the normal picking period whichever is the earlier. In general it will be found that light crop fruit should be picked about two weeks before heavy crops in the same orchard. Potentially light crop trees should receive a minimum of pruning, tillage, irrigation, and particularly nitrogenous fertilizers as all these are likely to increase the size of the fruit and liability to deterioration.

Section 12. Revised Nomenclature of Bitter Pit Complex

In 1929 the writer and his colleagues (Carne *et al.* 1929) attempted to classify the various disorders previously called bitter pit. Increasing knowledge has made this classification untenable. The following shows the relation between the disorders listed in the above bulletin, by McAlpine in his bitter pit investigations (1911-1916), and in the present publication.

McAlpine	Carne, Pittman and Elliot	Present Classification
Jonathan spot ..	Jonathan spot ..	Jonathan spot (in part) Lenticel blotch pit (in part)
Bitter pit	Storage pit ..	Storage pit
Bitter pit	Tree pit ..	Tree pit and crinkle pit
Confluent pit or crinkle ..	Internal cork ..	Internal cork
Confluent pit or crinkle ..	Drought spot cork ..	Crinkle and watercore sunburn
Confluent pit or crinkle ..	Crinkle cork ..	Crinkle
Bitter pit	Blotchy cork ..	Blotchy tree pit
Bitter pit	Orchard pitting ..	Tree pit and crinkle pit

The view frequently held that all bitter pit originates in apples while on the tree has arisen in part from the confusion of several disorders as shown above. When those due to watercore and boron deficiency are omitted it will be found that the experimental evidence demonstrates that tree and storage pit are distinct, the latter never originating on the tree. As suggested by Smith (1926) the evidence shows that although the susceptibility is the same, its translation into the active killing of tissues is due to different factors in each case. The operative factors for tree pit are to be found in the orchard environment of tree and fruit, and for storage pit in the maturity of the fruit when picked and the conditions of storage (Carne *et al.* 1931). At any time during its period of susceptibility an apple is more liable to storage pit than tree pit.

Section 13. Crinkle and Crinkle Pit

(*a*) *Crinkle* (Carne and Martin 1934)

Other popular names for this disorder are pig face and monkey face in Australia and York spot and hollow apple in U.S.A. There has been considerable confusion in the naming of crinkle. It is the confluent pit of McAlpine (1911-1916), the crinkle cork of Carne, Pittman and Elliot (1929), heat injury and York spot in U.S.A., &c.

As here used crinkle is a disorder following early watercore (Carne and Martin 1934). It usually develops after heat waves during late December to February.

Crinkle (Figs. 23-25) is recognized by the occurrence of one or more depressed areas, often to one side, and almost invariably mainly on the calyx half of affected apples. Normally, and always in the earlier stages, the skin in the depressions is not discoloured but may appear darker than normal. Later the skin may show sunburn injury. Beneath the depressions will be found a layer, usually under 1 cm. in thickness, of dead brown cortical tissues.

The surface symptoms start as water-soaked areas which later become depressed. These depressions range from rounded spots (crinkle pit) about 0·2 cm. in diameter to large irregular areas tending to form a zone around one-half or more of the fruit. The internal lesions start as a browning in and around the watercored tissue beneath the skin to a depth usually not exceeding 1 cm., but occasionally much deeper. As the browned tissue dies and dries out, it shrinks and is followed by the surface collapse. In advanced stages the dry dead tissue usually forms a layer 0·2 to 0·5 cm. thick beneath and parallel to the depressed surface. The dead tissues may develop cavities.

The association with watercore as a rule can be found only in the early stages of crinkle formation, and not at harvest time. Usually it can be found in light crops of varieties susceptible to early watercore about ten days after a January heat wave, particularly when it has been followed within a week by a second heat wave.

Crinkle has its origin in the interference of watercore with respiration, during periods of abnormal fruit temperatures. The breakdown is of the same soggy type as develops when apples are stored in an atmosphere free from oxygen (Section 19—Alcoholic breakdown).

Several variations from normal crinkle have been noted:

(i) The whole or greater part of the surface of apples is rough and underlaid by a very shallow zone of dead tissue 0·1 to 0·2 cm. thick. This has been found on Yates and Dunns following abnormal heat waves. It was preceded by an unusual surface form of watercore about 0·5 cm. deep, confined to the outer cortex (Section 11).

(ii) In Worcester Pearmain crinkle usually appears as an exaggeration of the "pearmain" neck on one side with little evidence of dead tissue beneath. The underlying tissue is slightly discoloured, and the surface may show some sunburn injury to the skin.

(iii) Instances have been noted where fruit known to have early watercore when placed in cool storage, has developed crinkle in or after cool storage. Crinkle is occasionally found in susceptible varieties of Australian apples when examined in England. This had evidently developed after packing.

Because of its association with early watercore it follows that varieties subject to that disorder are subject in some degree to crinkle. Early varieties like Worcester which may occasionally get early watercore in January are more subject to crinkle than later varieties like Rokewood which do not usually show early watercore before March though very liable to it. The green and yellow varieties French Crab, Stone Pippin, London Pippin, and Dunns are very susceptible, especially large and light crop fruit. Rome Beauty, Democrat, Jonathan, and Worcester are not infrequently affected when in light crop. It has been occasionally noted in light crops of Cox, Sturmer, Granny Smith, Rokewood, and Yates.

Diagnosis.—Crinkle has been confused with tree pit (Section 14), internal cork (Section 32), and with dimple (Section 16). The occurrence of shallow layers of dead tissue parallel to the surface depressions or larger masses of dead tissue, often with cavities, extending to but not involving the skin, are reliable evidence for diagnosis.

(*b*) *Crinkle Pit*

This is one of the several disorders usually known as bitter pit. It closely resembles tree pit and is not always separable (Figs. 27, 28). It is rarely important except in light crops of Granny Smith and French Crab.

Crinkle pit is recognized as spots or sunken pits from 0·1 to 1·0 cm. in diameter on the surface of apples. The spots or pits are rounded, stellate or irregular and dark green to brown or almost black but never light brown in colour. The colour comes mainly from the lesions under the skin. They are few, usually two to five and rarely exceeding ten per fruit.

The internal lesions are dark brown to almost black usually close to the surface, and of the same diameter as the surface spots. Normally the internal lesions are developed or initiated while the fruit is on the tree but the surface spots may only become evident after picking. They are not infrequently found in fruit with crinkle or in otherwise sound fruits from the same trees.

Observation indicates that it is a later form of crinkle developed in fruits which had largely recovered from early watercore and of which only residual patches remained in the cortex. Because the spots frequently show up only about picking time or after, the association with watercore is often difficult to find. It was noted in England that while some crinkle (with watercore often present) could be expected in susceptible varieties of Australian apples in the earlier shipments this was replaced in later shipments by crinkle pit. In neither case could the disorders be regarded as important in export, as the apples affected with crinkle were few and the lesions in crinkle pit were rarely numerous enough on an apple to warrant adverse comment.

In general the varieties subject to crinkle pit are those subject to crinkle. However, in Granny Smith, Jonathan, Sturmer, and Democrat crinkle pit is more common than crinkle. In Granny Smith in particular it may be an important form of tree pitting in some districts, as in the metropolitan areas of Sydney and Melbourne, especially when the trees are in light crop. In most other areas crinkle pit on Granny Smith and other varieties is confined to young trees and regrafts or to very light crops and is commercially unimportant.

Diagnosis.—Crinkle pit can be easily confused with forms of both tree and storage pit. The following points help diagnosis:

(i) Association with known occurrence of watercore and crinkle in the same variety in the same orchard.

(ii) Relatively few surface spots on a fruit either before or after picking.

(iii) Surface spots dark brown, dark green, or almost black, never light brown.

(iv) Pits often stellate or irregular in French Crab and Jonathan.

(v) Greater occurrence in later than earlier picks, both in fresh picked and stored fruit.

Section 14. Tree Pit

This disorder is one of several (storage pit, crinkle, crinkle pit, cork, &c.) collectively known in Australia as " bitter pit ". As this usage implies a common origin it has been abandoned in this classification (Section 12). Instead the several disorders are dealt with under their specific names.

Tree pit is characterized by relatively small lesions in the cortex, some of which extend to, and involve the skin. The surface symptoms are discoloured spots or pits. It always originates while the fruit is attached to the tree, though occasionally the lesions, especially those involving the skin, may not become apparent until later if sufficient time has not lapsed before the fruit is picked. In the latter case it is usually associated with storage pit.

(*a*) *Forms of Tree Pit*

Three forms are recognized which may occur separately or together.

(i) *Normal tree pit.*—This is probably the stippen of Europe and the original bitter pit of Cobb (1895). The external symptoms are dark green to yellow or brown spots showing through the skin or rounded brown to almost black depressed spots (pits) in the skin. The size of the spots is usually 2 to 3 mm. with a range of 1 to 5 mm. They occur mainly on the calyx half of the fruit. The internal symptoms are light to dark brown lesions located anywhere from the core line to the skin and usually within 1 cm. of the latter but never in the core. Starting as watery light brown areas they become defined, dark in colour, dry and spongy. The brown tissue contains starch which may be present as normal grains or in amorphous degraded masses.

(ii) *Red tree pit or pudding spot.*—This form differs from the normal in that the surface pits are bright red. They are usually under 3 mm. in diameter. Pudding spots are found in small numbers in association with normal tree pit in the cooler districts as in Tasmania and Southern Victoria, and especially on Cleopatra.

(iii) *Blotchy tree pit.*—This is the " blotchy cork " of Carne *et al.* (1929), an obsolete name as " cork " is now reserved for disorders associated with boron deficiency. Blotchy tree pit (Fig. 30) differs from normal tree pit in that the surface pits are larger, often irregular, and unevenly depressed, with the colour a deep brown or green blotched with brown. The internal lesions rarely show normal starch grains. Instead the starch is present in irregular amorphous masses. This form occurs mainly in the hotter climates of the mainland.

(*b*) *Varietal Liability*

In the cooler climates Cleopatra and Cox are perhaps the most liable of the major varieties. In the hotter climates some others including Sturmer and Ribston are also very liable and consequently are rarely grown. Many other varieties show some liability under severe climatic conditions and when in light crop.

Susceptible varieties all show a complicated system of starch loss (Carne *et al.* 1929, 1931) which forms a pattern in the cortex of closely associated starch free and starch filled tissues. The starch persists longest in association with the vasculars, particularly the branches from the main core line vasculars and the capillary network near the skin.

(*c*) *Incidence of the Disorder*

Tree pit is liable to appear on susceptible varieties any time after the fruit shows starch-free areas in the cortex. In normal crops new lesions cease to develop before the fruit reaches picking maturity for export or long storage. In light crop fruit they may still be developing at the normal picking time. Once formed the lesions do not increase in size.

(*d*) *Conditions Favouring the Disorder*

Relative varietal susceptibility is the same as for storage pit (q.v.) but to a lesser degree. Susceptible fruits have a greater potential storage pit liability than they have tree pit liability. Susceptibility starts when the first evidence of starch-free tissues can be found outside the core and continues until such areas predominate.

Within a variety liability increases sharply as the size of the crop decreases and average size of fruit increases. Amongst the fruits of an individual tree, liability varies largely with their size but not entirely as position is a factor. If any fruit in a cluster is affected all are likely to be affected. Fruits towards the ends of leaders and laterals are more liable than those lower on the limbs. Given fruit susceptibility the onset of the disorder is determined by climatic factors operating during the susceptible period. The main factors are those associated with high transpiration from the leaves combined with insufficient moisture intake to make up the deficiency. Under such conditions it is believed that the loss of water from the fruit to the leaves leads to the death of some of the starch-laden tissues. The deficiency of water is concentrated in these tissues because of the low osmotic pressure of their sap. If this view is correct it would explain the association of high liability with:

(i) Large fruit because the size of a fruit is directly related to the number of leaves sustaining it.

(ii) The calyx half, because it is the last to lose its starch and because, as in blossom-end rot of tomatoes and similar disorders, the points most distant from the stalk are the most affected by water deficiencies.

(iii) Fruits near the ends of leaders and laterals, because of their greater distance from the source of water supply in the tree.

(iv) All fruit in a cluster, because such fruits being dependent on the same water supply channel act in effect as one very large fruit.

(v) Light crop fruit because, in addition to its large average size, it has a greater starch content and a later starch disappearance than good crop fruit. This results in a greater and more prolonged demand for water for starch hydrolysis above that needed for transpiration.

The main causes of water deficiency are warm to hot dry winds causing high leaf transpiration and, in areas of fairly regular summer rainfall, shallow soils which dry out rapidly in periods of temporary drought. Of course, without such regular rains or irrigation apples cannot be grown on shallow soils. Of the two factors, high transpiration is the more important, and if severe enough will cause tree pit even when the soil moisture is not deficient.

Attention is drawn to the probable main difference in the origins of tree pit and immaturity watercore (and the crinkle and crinkle pit derived from it). While pit is apparently due to water deficiency in apples showing starch-free areas, immaturity watercore is apparently due to abnormal starch hydrolysis caused by heat acting on immature apples, combined with a sufficient water intake to meet the osmotic demand. Liability to immaturity watercore precedes that of tree pit in varieties susceptible to both and does not require the presence of starch-free areas in the flesh (Carne *et al.* 1931).

(*e*) *Possible Confusion in Identification*

The following disorders may be confused with tree pit:

(i) Storage pit (Section 15). Not always separable in stored fruit.

(ii) Crinkle pit (Section 13). This can usually be recognized by the darker colour and the relatively few lesions, which are free from starch. A reasonable range of affected fruits is desirable.

(iii) Internal cork (Section 32). Easily recognized by the frequent presence of malformation, lesions in the core, and the absence of surface spotting.

(iv) Hail marks (Section 26). Recognized by the absence of internal lesions free from the surface spots, by the occurrence anywhere on the fruit, and sometimes by the skin of the depressed spots being broken.

(*f*) *Control of Tree Pit*

(i) Avoid planting susceptible varieties in localities known to be favourable to tree pit or suspected as likely to be favourable, as on shallow quick-drying soils, and locations exposed to dry hot winds, especially when they cannot be protected by wind breaks. Varieties of low susceptibility include Yates, Dougherty, Crofton, Democrat, Dunns, Granny Smith, and Jonathan.

(ii) Rework susceptible varieties with profitable varieties of lower susceptibility.

(iii) Avoid heavy pruning of susceptible varieties especially after a heavy crop year.

(iv) Reduce or abandon nitrogenous fertilizers in the season following a heavy crop.

(v) If water is available keep the fruit growing during droughty periods. Restrict watering of trees during the pit-susceptible period to sufficient to maintain steady fruit growth.

Section 15. Storage Pit

This is one of the disorders still frequently known as bitter pit (Section 12). It differs from tree pit in the fact that it develops only in apples which have been picked or otherwise partially or wholly disconnected from the tree. Usually it is possible to distinguish tree and storage pit given a knowledge of variety behaviour and a reasonable range of specimens.

(*a*) *Forms of Storage Pit*

(i) *Normal storage pit.*—The external symptoms (Figs. 14, 15) are yellow to brown spots showing through the skin and/or rounded brown to dark-brown spots (pits) in the skin. The spots are usually 2 to 3 mm. in diameter but may range up to 5 mm. in susceptible varieties like Cox and down to 1 mm. in those of low susceptibility like Worcester and Jonathan. The internal lesions (Fig. 13) are brown areas on the flesh similar in diameter to those of the surface pits, and invariably containing starch grains. The lesions are found outside the core line and mainly within 1 cm. of the skin.

Normal storage pit occurs mainly towards the calyx end and usually more on non-flushed than on red surfaces. It may develop at any temperature, the rate of onset increasing with the temperature.

(ii) *Severe cool storage pit.*—In this form the surface spots (Figs. 11, 15) are larger, darker, deeper and more defined than in normal storage pit with which it is often associated. The individual pits are usually round but may be confluent, forming irregular areas. The internal lesions (Fig. 13) are usually close to the surface.

This form has been noted only in severely pitted light crop fruit held in cool storage. Sometimes it has been found affecting practically the whole surface even of varieties of relatively low susceptibility such as Dunns and Granny Smith when picked very early in the susceptible period.

(iii) *Lenticel blotch pit.*—This is the lenticel blotch of Carne *et al.* (1929, 1930). It is a form of severe shallow pitting occurring in light crop fruit of red varieties, notably Jonathan and Spitzenberg, when held at warm temperatures. However, it may not be noticed until delayed storage fruit has been in cool store some time. It has been observed to develop seriously in light crop fruit which has been packed and held at about 60°F. or more for 10 to 14 days. The surface blotches (Fig. 14) occur mainly on red surfaces and are more irregular and usually larger than other forms of storage pit. They are frequently irregularly depressed. The internal lesions are normally shallow and directly connected with the surface blotches, and are usually removed with ordinary peeling. For this reason the disorder has been often confused with Jonathan spot (Section 17). Usually, however, a few normal storage pit lesions can be found deeper in the flesh. Unlike other forms of storage pit the surface blotches are subject to fungal infection as the fruit ripens.

This disorder may have some relation to Jonathan spot as both attack the same varieties. While, however, Jonathan spot liability tends to increase with maturity at picking time, the reverse is true for lenticel blotch, though both may occur in the same apples. Both increase with the temperature of storage.

(b) *Varietal Susceptibility*

The most susceptible varieties include Cox, Ribston, and Cleopatra. Many others show liability, especially when in light crop, including Jonathan, Granny Smith, Alfriston, Dunns, Rome Beauty, Gravenstein, and Sturmer. Varieties which rarely show storage pit include Yates, Crofton, Dougherty, King David, Worcester, Statesman, Democrat, Scarlet, French Crab, King Pippin, Stone Pippin, London Pippin, Tasman's Pride, Delicious, and Rokewood, though most of these can be induced to pit by picking very light crops early in the susceptible period.

Susceptible varieties (Carne *et al.* 1929) show a system of starch loss which produces an intricate pattern of closely associated starch-containing and starch-free tissues. Starch persists longest around the main vasculars in the cortex and in the capillary vascular network close to the skin. Varieties of low susceptibility show a more or less uniform starch loss. This is particularly true of varieties like Yates which is practically never pitted.

(c) *Incidence of Pitting* (Carne *et al.* 1930)

If immature enough (Fig. 20), apples of susceptible varieties can be picked without danger of pitting but they never ripen. As soon as the starch-free areas indicative of maturation can be found in the cortex (Fig. 20) liability to pit commences and rapidly rises to a maximum. With further starch loss (Figs. 21, 22) liability declines and disappears at a stage determined by the various factors influencing susceptibility. The length of the susceptible period and degree of susceptibility depend upon the variety and the size of the crop and fruit (Carne and Martin 1938*b*). In large light crop fruit, susceptibility may continue well into the usual picking period (Carne 1940). With susceptible varieties pitting liability may persist in light crop fruit beyond the safe picking period for storage or export.

As already stated the onset of pit liability in susceptible varieties starts with the first evidence of starch-free cortical tissues. However, the normal increase of susceptibility to a peak and subsequent slower decline as maturation proceeds to picking maturity may be upset under certain conditions. Heavy crops of small fruit which grow steadily have a low maximum susceptibility. If, however, the fruits are small because of drought they tend to mature late. Heavy rain or irrigation during the susceptible maturation period, which results in a rapid increase in fruit size, also causes it to show stationary or even increasing starch content, and increasing pit liability, followed later by a decline in starch content and pit liability. As a consequence pit liability about the ordinary picking time may be greater than before the rain or irrigation. This increase of pit liability following rain or irrigation has been noted by many investigators (Tindale and

Huelin 1943; Brooks and Fisher 1918, &c.), but the effect on fruit size and starch content has not been recorded. The author has noted a number of commercial occurrences of increased pitting following rapid fruit growth after rain or irrigation. In one instance in Western Australia the failure of a block of Cleopatra trees to give sufficient size in its fruit led to a late irrigation. The fruit responded. Though the last picked block of the variety in the orchard its fruit was the least mature in relation to starch loss and suffered most from storage pit, though no larger in average size. A somewhat similar result may follow partial early picking which results in the remaining fruits growing as large or larger than those originally picked. If picked while still susceptible, such fruit may develop as much pit as the original picking.

Pitting appears to be related to a deficiency of available moisture for starch hydrolysis in the starch-containing cells when the fruit is cut off from its source of supply, namely the tree. Osmotic gradients are set up which concentrate the moisture deficiency in the starch-containing cells. This view agrees with the following observations:

(i) At any given stage of starch loss the total water requirement is greatest in the largest fruits.

(ii) Light crop fruit contains more starch and loses it later than heavier crop fruit and so contains more starch at the same picking time.

(iii) Light crop fruit is larger and in appearance and edibility is earlier than heavier crop fruit and consequently is usually picked earlier.

(iv) Starch loss in the cortex is earlier at the stem than the calyx end, and the latter is consequently more liable to be affected.

(v) Starch hydrolysis is more rapid and the incidence of pit earlier at higher than lower temperatures. Cool storage delays pitting but tends to increase its final incidence. Maximum incidence is at moderate temperatures (about 50°-60°F.), and least at high temperature (70° or more) (Allen 1931).

(vi) Pit lesions always contain starch.

(vii) Surface coatings which reduce transpiration may reduce pitting (Tindale and Huelin 1943).

(*d*) *Possible Confusion in Identification*

(i) *Tree pit* (Section 14).—No difficulty occurs in distinguishing either red or blotchy tree pit from storage pit. There is, however, no clear distinction between small lesions of normal tree pit and normal storage pit. It is probable that there are no real symptomatic differences as the two disorders differ only in the reason for water shortage in the fruit. During the period of high water requirement by the fruit, the act of picking is a more drastic and general cause of pitting than is high leaf transpiration. Fruit which is in the susceptible condition for tree pit is more liable to storage pit if picked.

(ii) *Crinkle pit* (Section 13).—The dark colour, freedom from starch, and limited number of lesions are usually sufficient to distinguish this disorder.

(iii) *Hailmarks* (Section 26).—The absence of lesions in the flesh not connected with surface spots, their occurrence anywhere on the surface of a fruit, and the occasional rupture of the skin, are sufficient to identify hail injury.

(iv) *Jonathan spot* (Section 17).—This is a discoloured skin spot not or only barely depressed and without independent internal lesions.

(v) *Fleck* (Section 19).—This is a senescent disorder of over-stored fruit usually showing little external evidence but resembling pit when the fruit is cut. The internal lesions appear as small spots, flecks, or streaks and are due to the death and browning of individual vasculars. In pit the lesions consist of a rounded mass of tissue involving one or more vasculars.

(*e*) *Control of Bitter Pit*

(i) Rework very susceptible trees to less susceptible varieties. Plant only varieties of low susceptibility.

(ii) Avoid premature picking of trees with fair to moderately heavy crops. Especially avoid very early picking of trees with light crops to prevent the fruit becoming too large.

(iii) Pick with special care trees showing more than unimportant amounts of tree pit. Preferably the fruit should be picked for immediate sale, as it usually takes about ten days for storage pit to become evident. If the fruit is to be cool-stored, delay picking as much as is safe and store the fruit separately. Store promptly after picking. After removal from cool store cull and sell promptly or if early consumption is not possible hold for a week or more at ordinary temperatures to allow most of the fruit which will pit to be removed before packing.

(iv) Keep fruit from light crop trees separate from that of heavier crops of the same variety.

(v) Size grade susceptible varieties before cool storage.

(vi) Market each susceptible variety from cool store in the following order: large light crop fruit, smaller light crop fruit, then good crop fruit commencing with the largest sizes.

(vii) Do not ship light crop fruit overseas.

(viii) To reduce liability in susceptible varieties:

(1) avoid heavy pruning,

(2) avoid nitrogenous fertilizers after a heavy crop,

(3) aim at steady fruit growth; do not allow trees to become dry and then water during the pit susceptible period.

Section 16. Dimpling

This is a form of fruit malformation (Fig. 31) consisting of one or more irregular or rounded dimples or depressions, mainly on the calyx halves of the fruit. At the base of each dimple there is usually a small spot of cork tissue suggesting a skin puncture and about 1 mm. in diameter. There are no internal lesions. It appears to be practically confined to a few varieties including Granny Smith and, to a less extent, Cleopatra, Delicious, and French Crab. It ranges in severity from quite unimportant to malformation so extensive as to render the fruit unsaleable. In the severest forms it may not be distinguishable from internal cork due to boron deficiency except by the absence of internal lesions and the lack of response to borax.

(*a*) *Types of Dimpling*

Dimpling has been noted as occurring in two ways:

(i) *Recurring dimple.*—The same trees are affected every year in some varying degree with from 5 to 100 per cent. of the fruit showing symptoms. In the worst cases the whole crop on a tree may be useless. It has been observed recurring in groups of anything from 1 to 50 trees. Scions from unaffected trees grafted on affected trees have produced dimpled fruit, but affected scions have produced sound fruit on unaffected stocks. There is a definite locality association, but no association with climate or soil has been observed. It is worse in light crops. It has been found severe to very severe on Granny Smith and from unimportant to moderately severe on Cleopatra. This disorder may be the " green crinkle " of New Zealand.

(ii) *Sporadic dimple.*—In this case, which is widespread in mainland Granny Smith plantings, slight and negligible dimpling is not uncommon, especially in light crops. In some seasons, particularly in Western Australia, the malformation may be severe and a considerable proportion of the affected crops reduced in quality to Good or Factory Grade. It is most marked in light crops which have suffered from drought during the main growing season.

(*b*) *General*

Both forms of dimpling usually first become apparent about November. The recurring form, which usually leads to removal of the trees, occurs more or less every year. The sporadic form is usually associated with light crops, especially under drought conditions. Given a good growing season after November the fruit tends to " grow out " of the latter trouble and becomes practically normal in appearance.

In both disorders the first symptoms are minute patches of corky tissue on the skin. As the fruit grows, growth is restricted at the affected points, resulting in the surface depressions. Each corky spot is associated with a main branch from a core line vascular which extends to it. This vascular and the adjacent cells are often injected with water which is rich in sugar, forming a narrow strip of watercore. In slight or grown-out dimples evidence can sometimes be found that a capillary vascular has become enlarged to connect the affected area with another main cortex vascular. This would suggest that a main cortex vascular not functioning properly is the cause of the restricted growth, and that this may be overcome by another cortex vascular taking over part of its functions through a capillary branch.

(*c*) *Causes of Dimple*

The causes of dimpling are unknown. Externally the recurring type resembles internal cork due to boron deficiency but it does not respond to borax. It closely resembles the illustrations of " false sting ", a virus disease described in Nova Scotia (Hockey 1943), but grafting experiments in Tasmania indicate that it is not due to a virus. The weight of evidence suggests that the cause is due to a deficiency of some minor element which is increased by drought. However, unpublished work by Martin in Tasmania has given negative results with various minor elements. Sporadic dimple resembles some forms of frost dimple (Section 27) but occurs in districts and seasons where temperatures as low as freezing point have not been recorded and no other evidence of frost damage has been found. It has not been associated with insect punctures. Malforming insect injuries in Australia in very young apples are mainly caused by bites of insects such as grasshoppers and moth larvae and not by sucking or ovipositing punctures. The corky or russety patches so formed do not cause dimples and indeed are often raised, as a result of growth stimulation, to form warts.

Both types may be confused with the depressions of split core in Cleopatra with which it may occur, but in that disorder there is no corky tissue in the depressions which also are usually elongated rather than rounded.

Section 17: Superficial Skin Spots

This section includes various spotted lesions and discolourations of the skin which are confined to the epidermal tissues. It excludes superficial spots which are associated with flesh lesions in the same fruit. There is, however, no clear distinction between some of the spots in this section and those listed under superficial scalds (Section 18). Both sections should be consulted.

(*a*) *Jonathan Spot*

This is a disorder (Figs. 32, 33) of red varieties, notably Jonathan and Spitzenberg, and, to a lesser extent, Rome Beauty, Scarlet, and Worcester. Other spotting disorders including lenticel storage spot (Section 18) and lenticel blotch pit (Section 15) have been confused with Jonathan spot.

Commercially Jonathan spot is a disorder of stored fruit, its onset being affected by the temperature and conditions of storage. At ordinary air temperatures with little protection against loss of water from the fruit it may appear in 6 to 8 weeks, but in cool storage usually not before 3 to 4 months. The fruit may become affected on the tree if it becomes tree ripe without falling. It is not associated with light crops and large fruit. Instead, heavy crops are usually the more affected. Small fruits are at least as liable as larger and probably more so in the mass, though from an individual tree the larger are the more affected (Carne and Martin 1935*c*).

The spots are at first ill-defined, dark red or brown on red skin and greenish yellow to brown on yellowish skin and mainly on the cheeks of the fruit. They do not necessarily originate at lenticels. In time the spots become more defined, darker, and very slightly sunken. At this stage they frequently show a dark ring border (Fig. 33). They are not subject to fungal infection. Affected fruit has been over-stored and although not necessarily over-ripe or mealy, has lost much of its crispness and flavour. Ordinary spot rotting may appear at this stage but rarely in the Jonathan spots.

Conditions favouring Jonathan spot.—(i) Well coloured lines of fruit from heavy crops including the less coloured inside fruit from the same trees. (ii) Late picking. (iii) Storage at ordinary air temperatures especially under conditions of excessive ventilation. (iv) Delay before cool storing after picking. (v) Slight injury from oil or arsenical sprays not sufficient to cause fruit to be rejected at the time of storage. (vi) It is suggested that a major cause is the excessive loss of moisture from susceptible varieties. Varietal liability appears to be associated with strong red skin pigment especially when combined with a low production of natural skin wax as the fruit matures.

Control.—Jonathan spot is controlled by gas storage, oiling, or waxing; these reduce respiration and retard ripening, the effect being due to the increased carbon dioxide content of the fruit. A more simple method is to avoid late picking and over-storage.

(*b*) *King David Spot*

Dark red, brown, or greenish superficial spots on the King David apple usually occurring at the stem and/or calyx ends especially in the basins. Little is known of this minor disorder which appears to develop in mature fruit before picking though it may become more marked in storage. The spots do not become depressed. Earlier picking is the principal means of prevention.

(*c*) *Lenticel Blotch* (Section 15)

A form of storage pit (Fig. 14) occurring mainly on light crop Jonathan and Spitzenberg and often confused with Jonathan spot, with which it is sometimes associated. It differs from Jonathan spot in being confined mainly to early pickings of light crop fruit. The irregular, depressed, defined spots are darker (nearly black), larger, and with underlying shallow brown lesions which are usually removable by peeling. They are usually accompanied by at least a few normal pit lesions in the flesh.

(*d*) *Lenticel Spots*

Superficial brown to black spots centred on lenticels. They result from the death of the tissues around and immediately beneath the lenticels. Being subject to fungal infection they are frequently followed by spot rotting. Three general forms are recognized:

(i) *Orchard scald* (Section 18).—Fruit left too long on the trees develops a skin and lenticel scald (Fig. 37). Mainly a trouble of late varieties such as Sturmer. It is a form of light-induced scald.

(ii) *Lenticel storage spot* (Section 18).—Developed in over-stored fruit.

(iii) *Chemical spotting* (Section 31).—This may be caused by skin treatments with oils, waxes, &c.; acid baths for removing arsenical spray residues; fumes from freshly cut karri and cypress pine timbers; and ammonia fumes from leaks in ammonia refrigerating units.

(*e*) *Lenticel Storage Scald* (Section 18)

A spotted brown discolouration (Fig. 36) of the lenticels usually associated with and passing into the continuous brown areas of typical superficial scald. Developed in cool storage or at least under conditions of very restricted ventilation, it is found mainly on green and yellow varieties.

(*f*) *Hail Spots* (Section 26)

Small hailstones cause superficial depressed brown spots overlying small shallow bruised lesions. They resemble storage pit but are without the flesh lesions of that disorder. They may be recognized in a reasonable range of samples by:

(i) The spots are usually grouped but not on any particular part of a fruit.

(ii) The lesions increase in size and depth with the surface spots and in the larger can be recognized as bruises.

(iii) Some of the spots may show broken skins cut by jagged hailstones. Some fruits may show severe injury even to the extent of pieces of flesh being cut away.

(*g*) *Insect Stings and Bites*

These cause surface lesions ranging from small corky spots to relatively large brown russeted grooves, rounded areas, and warts.

Stings may be defined as punctures caused by sucking and egg-laying insects or much more frequently in Australia by the entry holes of codling moth larvae. If eggs do not hatch or if the moth larvae die before penetrating deeply, the injuries heal and become evident as small dry corky spots. The fruit is not malformed.

The larger irregular brown grooves and more or less circular depressed or raised spots are due to injuries caused by biting insects, such as the surface feeding larvae of the brown apple moth (*Tortrix* sp.) and looper moth (*Phrissogonus* sp.) or the adult stages of some grasshoppers. The exposed flesh heals and as the injured surface expands with the growth of the fruit new surfaces develop, the remains of the older being evident as a flaky scurf or russet.

Section 18. Superficial Scalds

As used here the term superficial scald covers types of discolouration, not due to russet, parasites, or mechanical causes, which affect only the skin and subepidermal tissues. They are completely removed when the apples are peeled in the ordinary way. This section does not include deep, soft, or Jonathan scald which is the disorder frequently meant by the term scald in some Australian States. This, and heat scald, are included in Section 19 as forms of breakdown. The superficial scalds include the following types:

(*a*) A general often ill-defined discolouration of the skin, as in storage scald.

(*b*) Defined often slightly sunken discoloured areas, as in light-induced scald.

(*c*) A spotted discolouration which may or may not be associated with the lenticels as in lenticel scald and Jonathan spot.

(*d*) A superficial browning associated with darker sunken irregular blotches and attributed to freezing injury (Section 27).

On the basis of time of origin, the various types may be divided into three groups:

(*a*) *Orchard Scalds*

These originate in the fruit while on the tree or in packing plants before placing in common or cool storage.

(i) *Sunburn* (Section 29).—This is a bleaching or browning of the skin (Figs. 26, 41) which may become darker and more apparent after storage.

(ii) *Spray injury* (Section 31).—This includes the skin staining or browning and brown to black spotting caused by spraying with excessive concentrations of sprays or during very hot weather. Oil, copper, arsenical, and sulphur spray compounds may be responsible.

(iii) *Acid bath injury* (Section 31).—Hydrochloric acid baths for the removal of arsenical spray residues from apples may cause spotted or general scalding of the calyx and stem basin and also core injury if the solution is too strong or too hot or the apples are insufficiently rinsed in water. Injury may also be caused by the accumulation of arsenic in the acid bath or rinsing water.

(iv) *Green timber injury* (Section 31).—Brown more or less sunken spots and areas on the skin resulting from packing apples in boxes of sappy green cypress pine and karri timber and probably other timbers. Similar in appearance to the severe form of light-induced scald (Fig. 40).

(v) *Orchard scald.*—A general ill-defined or spotted dirty brown discolouration (Fig. 37) of the yellow or yellowish skin of mature apples which have been allowed to ripen on the tree or in boxes exposed to the weather. It is found mainly on late varieties which hang well on the tree. The spotted form is associated with the lenticels and is subject to fungal infection and subsequent spot rotting. Orchard scald is a form of light-induced scald (Section 30) at least in part.

(*b*) *Storage Scalds*

These originate in cool or common storage. In cool-stored fruit they may become apparent only when the fruit has reached a normal air temperature after cool storage.

(i) *Early superficial scald.*—This is the "apple scald" of North American usage. The term superficial scald was first proposed by Tiller (1929) to distinguish this disorder from deep scald. Though usually a disorder of certain varieties in or subsequent to cool storage, it may occur in badly ventilated common storage, a rare thing in Australia where apples not in cool storage are usually held in well ventilated sheds or in boxes under temporary cover amongst the trees.

Early scald is a continuous brown to almost black skin discolouration (Fig. 36) varying from ill-defined to fairly sharply defined areas, but often with the lenticels similarly discoloured outside the main affected areas. This spotted discolouration is distinguished as lenticel scald. Superficial scald should be distinguished from late scald, a low temperature disorder.

Varieties normally picked when the green ground colour has shown little or no evidence of changing to yellow, and varieties with little or no red pigment in the skin are the more susceptible. Liability to scald is further increased by skin injuries such as bruises, punctures, sunburn, acid bath and spray injury, &c. The flesh is not affected and the fruit is not made susceptible to rots unless held until the apples become senile. The affected skin may then be rubbed off easily and the flesh exposed to fungal attack.

Storage scald may be initiated within 3 months, but usually does not become evident in under 4 to 6 months in cool storage according to the susceptibility of the fruit. However, once scald is initiated, removal to ordinary temperatures results in it becoming apparent in 2 to 10 days according to the temperature.

Susceptibility decreases with increase of maturity of the fruit when placed in the restricted ventilation conditions of cool storage. It is attributed to the accumulation of gaseous emanations from the fruit in the storage air (Carne and Martin 1935*a*).

Lenticel scald.—This is a spotted form of storage scald (Fig. 36) which frequently accompanies the continuous form and rarely occurs alone. The small spots are brown to black, are not depressed, and are usually confined to the lenticels and immediately adjacent skin. They may coalesce and pass into a broken form of general scald. There is no special liability to fungal infection.

Possible confusion.—Sunburn renders the affected tissues susceptible to storage scald, and may be confused with primary scald. The same is true of the chemical injuries listed under orchard scald.

Factors favouring storage and lenticel scalds include:

(1) Immaturity of the fruit when stored.

(2) High orchard temperatures preceding picking. Tasmanian apples have a low susceptibility as compared with those from warmer areas. Late varieties are rarely affected.

(3) Slow cooling in cool storage.

(4) Insufficient ventilation. This includes gas storage in which ventilation is deliberately restricted to allow CO_2 from the fruit to accumulate to a predetermined amount, usually 5-10 per cent.

(5) Overlong storage.

Control of superficial scald.—Control methods include the following:

(1) Avoid premature picking of fruit to be cool-stored, except perhaps for short periods not extending beyond mid July.

(2) Do not use even slightly sunburned fruit for long cool storage

(3) Wrap the fruit in oiled wraps which should contain not less than 15 per cent. by weight of an odourless mineral oil or hold loose in a ventilated shed for 10 to 14 days before packing in oiled wraps and placing in cool storage. Delayed storage will hasten yellowing.

(4) Store as close to 32°F. as possible without danger of the temperature falling below 30°. This method is not recommended when low temperature breakdown is a danger.

Susceptible varieties include Granny Smith, Dunns, Delicious, and to a lesser extent Ballarat (Stewart's Seedling), French Crab, Rome Beauty, and Cleopatra, especially when grown in the warmer districts. Granny Smith and Delicious are the most affected in practice because they are often held for long periods of storage.

(ii) *Late scald.*—This is a dark, smooth, more or less defined, water-injected condition of the skin (Fig. 38) which may be found in cool-stored apples at or near the point of developing breakdown, especially low temperature breakdown. The colour depends upon the colour of the affected skin. Because they are more susceptible to low temperature injury, late scald has been found mainly in Tasmanian apples, including Alfriston, French Crab, and Crow Egg in which the preferred market colour is dark green, and Cox, Ribston, and Sturmer in which it is usually yellowish. In the three former it usually appears first at the stem or calyx ends. In the others it may appear on any part of the surface and often suggests what might be an early stage of deep scald (Section 19) though in fact no such stage occurs in that disorder. The colour tends to lighten with the onset of breakdown but becomes dull and muddy. Late scald frequently occurs in association with pit, bruises, and surface injuries (Fig. 39).

(iii) *Lenticel storage spot* (Lenticel spot of Kidd and Beaumont 1925).—This is a browning of and around the lenticels or skin injuries. The eventually depressed spots vary from pin points to areas up to 1 cm. or more in diameter. Yellow surfaces are more subject than red but both may be affected. The spots are subject to fungal infection especially as the fruit becomes senile. Their onset is delayed by oiled wraps and hastened by the presence of ripe apples in the same storage chamber (Kidd and West 1938).

Storage spot is essentially a disorder of ripe or over-stored fruit and consequently appears earlier in common than cool storage. It is usually followed by spot rotting. It has often been confused with Jonathan spot (Farrell 1924). All varieties are affected including Sturmer, Cleopatra, Democrat, Granny Smith, Jonathan, Rome Beauty. Storage spot may be confused with the lenticel spots caused by chemical injuries listed in Section 31.

(iv) *Jonathan spot* (Section 17).—A brown, greenish or yellowish spotting of certain red varieties when at or past optimum ripeness (Figs. 32, 33).

(v) *Lenticel spots.*—These are a miscellaneous collection in many cases following chemical injuries originating before storage but becoming more apparent with time. They will be found listed under orchard scalds. There is an exception due to ammonia injury (Section 31) for which leakage of ammonia from the refrigeration plant is responsible.

(vi) *Freezing scald* (Section 27).—Dark, sunken irregular blotches sometimes associated with atypical superficial scald.

(*c*) *Post-storage Scald*

There is only one scald which originates after storage. It follows exposure to light.

Light-induced scald (Section 30).—Brown discolouration of the skin of ripe apples exposed to sunlight. It varies from a general brown discolouration to defined sunken areas of the skin (Figs. 37, 40).

Section 19. Breakdown or Flesh Browning

In its typical forms breakdown is a general light to dark browning and death of the flesh, core, or vascular tissues. It may be progressive and ultimately involve the whole of the flesh and skin or it may be confined to specific tissues. Breakdown never starts in the epidermal tissues. The term is not used to include small localized flesh lesions such as occur in pit and internal cork but in some cases there is no clear division between the two types. This is particularly true for brown heart and fleck.

Breakdowns may be grouped according to type into:

(i) General breakdowns which when once started tend to involve all the flesh irrespective of any change of environment. These include various types of senescent breakdown.

(ii) General breakdowns which cease to develop when the casual environmental factors are removed but which are frequently followed by a general senescent breakdown. They include breakdowns caused by excess carbon dioxide, insufficient oxygen, and low or very high temperatures.

(iii) Localized breakdowns which do not extend beyond specific tissues. These include crinkle, deep scald, and core flush. They are not, at least for some time, followed by senescent breakdowns.

Or alternatively as:

(i) Primary breakdowns caused by senility or unsatisfactory environmental conditions. This group includes those due to excessively high or low temperatures, excess of carbon dioxide or insufficient oxygen in storage air, and over-maturity.

(ii) Secondary breakdowns which are senescent forms following on some prior injury, such as those following early and late watercore, bruises, pit, and primary breakdowns.

Breakdowns which extend to and involve or are visible through the skin are often referred to as scalds. As used in this publication scalds originate in the epidermal and subepidermal tissues and not in the flesh beneath. There is frequently an association of scald and breakdown but the separation of the two groups of disorders is justified by the difference in the points of origin.

When senescent breakdown approaches another form of breakdown in the same apple the two remain separated by a recognizable margin, which for some time is a white zone (Kidd and West 1925, Fig. 13). This does not occur when the same type of breakdown meets after originating at two or more separate points. A persistent separating zone also occurs between lesions of the pit type and senescent breakdowns (Fig. 16).

It should be recognized that any flesh injury may stimulate premature senility and hasten the onset of senescent breakdowns. For simplicity the secondary senescent types are classified according to the cause stimulating them. Attempts have been made by investigators to group breakdowns into senescent or mealy types and non-senescent or soggy types. Although this distinction holds fairly well there are many exceptions. In some varieties, as in Jonathan, all forms are mealy, and in others, as in Cox, the nature of the breakdown varies with the maturity of the fruit as well as with the cause.

As already stated secondary senescent breakdowns often follow primary forms. In addition, more than one form of primary non-senescent breakdown may occur in the same apple, as for instance brown heart and low temperature breakdown. A reasonable range of samples, including some showing the early stages of breakdown, is desirable for reliable diagnosis of primary causes. In advanced stages the breakdown may mask the primary causes, as in watercore breakdown.

The following classification is based firstly upon whether the breakdown is progressive or limited, and secondly, upon those causative factors which most readily lend themselves to control.

(i) *General senescent breakdowns.*—In these the affected flesh becomes brown, dry, and mealy and ultimately the whole of the flesh is involved. The senescence of the fruit may be normal or prematurely induced.

(*a*) Over-maturity breakdown.
(*b*) Early watercore breakdown.
(*c*) Late watercore breakdown.
(*d*) Pit breakdown.
(*e*) Bruise breakdown.
(*f*) Vascular breakdown or fleck.

(ii) *Partial or general non-senescent breakdowns.*—These develop only during the operation of the causal factors. The flesh becomes brown and is usually soggy but may be mealy. If the causal factor is removed the affected flesh usually dries out. They may be followed by a senescent breakdown.

(*g*) Low temperature breakdown.
(*h*) Brown heart or carbon dioxide injury.
(*i*) Alcoholic or oxygen-deficiency breakdown.
(*j*) Heat scald.
(*k*) Freezing breakdown.

(iii) *Localized breakdowns.*—These do not extend beyond certain specific tissues even when the causal conditions continue unchanged. Senescent breakdown may follow.

(*l*) Core flush.
(*m*) Corky core.
(*n*) Crinkle.
(*o*) Deep scald.

(a) Over-maturity breakdown (Synonyms: Jonathan, mealy, and senescent breakdowns in part) (Fig. 42).

This is the normal senescent sequence to ripeness of many varieties of apples when held too long in cool storage. In common storage the usual end of sound apples, especially the later varieties, is either rotting caused by fungi or a shrivelling and drying out. The first evidence in otherwise sound apples is a faint pinkish discolouration of the core (core flush) or of the vasculars and flesh near the core line. The flesh as a whole will then be found to be dry, mealy, and lacking flavour. The discolouration extends outward through the apple becoming progressively darker. The advancing edge is not defined but merges into the normal colour of the flesh. As it approaches the skin the apples become soft and non-resilient to pressure. Sometimes the skin may rupture and turn back exposing the flesh. Rots usually follow this breakdown.

Factors favouring the disorder.—Because of its association with maturity, its onset is hastened by late picking, delayed cool storage, and high storage temperatures.

Large apples are more subject than smaller from the same tree when picked at the same date. Light crop fruit is much more subject than heavy. Rapid fruit growth in the month preceding picking reduces the storage life, as in fruit which responds to autumn rains following a summer drought. Some flesh disorders such as watercore, pit, and bruises stimulate a premature senility and breakdown in cool-stored fruit even of varieties not particularly subject to over-maturity breakdown. These premature senescent breakdowns are described in the following sub-sections.

Susceptible varieties.—Varieties particularly subject to over-maturity breakdowns in otherwise sound apples include Jonathan, Rome Beauty, Gravenstein, Cox, and Ribston. Varieties of lower susceptibility include Worcester, Democrat, Crofton, Granny Smith, Yates, Dougherty, and Rokewood, in which storage life is usually terminated by rots, shrivelling, &c.

Breakdown of Immature Apples

This is a senescent cool storage breakdown of over-stored apples picked in too immature condition to ripen fully. It is usually preceded by core flush and frequently by superficial scald. It differs from ordinary over-maturity breakdown in that the flesh never passes through a stage of maximum flavour and juiciness. Usually the affected flesh is less mealy and the fruit less soft than with breakdown in ripe apples. This form has been noted mainly in varieties which are normally picked more or less immature to ensure a green skin ex cool store. They include Alfriston, Crow Egg, Dunns, and Granny Smith, all except the last being mainly used as culinary apples.

(b) **Early watercore breakdown** (Carne and Martin 1934)

This is a breakdown (Fig. 23) of premature senescence caused by the presence in the fruit of early or immaturity watercore (Section 11). It may develop in fruit on the tree or in common storage, especially in very early varieties like Irish Peach, but is mainly found in or subsequent to cool storage. The breakdown starts usually in and around the watercored areas, but in fruit which has matured in storage and has lost part or all of its watercore there may be no visible relation between watercore and the breakdown. Cases have been noted in Stone Pippin, Dunns, and Rokewood in which the breakdown started in tissues remote from the watercore, and resulted in surface depressions like crinkle or deep scald. In very immature fruit the breakdown may be confined to the waterlogged tissues.

In the latter case the injured tissue eventually dries out and the surface may collapse producing typical crinkle (Section 13). Generally the breakdown spreads through the fruit with the flesh at first wet and becoming mealy and light brown except in the watercored areas. If still present the latter can be recognized as dark watery areas which are translucent in slices. Because of the steady but slow disappearance of watercore in cool-stored fruit, the association of breakdown and watercore may not be evident in fruit which has been stored some months. Generally, the presence of watercore can be found if sufficient material is available for examination.

Control.—Susceptible varieties should be examined for watercore at picking time. If it is present to a significant extent the poorer keeping varieties should be marketed without storage. The better keeping varieties should be held a week or two at ordinary temperatures, or until the watercore has largely disappeared, before cool storage.

Varieties which should not be cool-stored if they have early watercore include Cox, Ribston, Rome Beauty, and London Pippin. Those which should be held before cool storage include Rokewood, Dunns, Democrat, French Crab, and Stone Pippin. The tissue injury and premature senescence appear to be due to the products of anaerobic respiration following insufficient oxygen intake of the watercored tissues.

(c) Late or radial watercore breakdown (Carne *et al.* 1930; Carne and Martin 1934. Synonyms: Jonathan, mealy, and senescent breakdowns in part)

This is a typical mealy senescent breakdown (Fig. 10) due to senility stimulated by late or radial watercore (Section 11) the presence of which indicates light crop fruit or over-delayed picking. Breakdown starts in or around the watercored tissues which are mainly associated with the core line and its main vascular branches. The injected tissues show as dark translucent patches in transverse slices of the fruit. Breakdown may occur while the fruit is on the tree, in common or cool storage, or after cool storage. It is generally not difficult to identify from the presence of the watercore and a mealy breakdown spreading more or less radially from the main core vasculars.

Radial watercore is an indication that picking has been left too late. Its discovery is evidence that the fruit should be picked at once. As the affected tissues do not recover their storage capacity, appreciably affected fruit should not be cool-stored, and slightly affected fruit only for a few weeks. Such fruit should be stored separately and the larger sizes marketed first. Varieties most affected include Jonathan, Ribston, Cox, Gravenstein, King David and Delicious.

(d) Storage pit breakdown (Carne *et al.* 1930)

This is a progressive senescent breakdown (Fig. 16) in over-stored fruit affected by storage pit. It may occur at any temperature. The higher the temperature the earlier the onset, provided the fruit is mature enough to ripen and not shrivel. It differs from ordinary over-maturity breakdown in appearing first in pit affected fruits and also in varieties not particularly subject to that breakdown in otherwise sound fruits. The dark brown mealiness of the flesh starts between and around the pit lesions from which it is separated by a distinct margin which frequently persists for some time as a white zone.

Liable varieties include Ribston, Cox, and Cleopatra. As storage pit liability is greatest in light crop fruit, such fruit should be placed in cool storage unwrapped. It should be sorted when packing, discarding the fruit with pit or breakdown.

(e) Bruise breakdown (Carne 1935; Barker *et al.* 1935) (Fig. 43)

This is a premature and progressive senescent breakdown stimulated by the bruising of ripe fruit. Like pit breakdown it starts in association with the flesh injuries from which it is for some time separated by a white zone. As susceptibility to both bruising and senescent breakdown increases with the maturity of the fruit, bruise breakdown is greatest in ripe fruit which has been held too long in cool storage or stored too late or at too high a temperature. Early pre-storage bruises usually dry out before the fruit ripens and do not stimulate breakdown. Bad packing or bad handling of fruit ex store increases bruising, but if the softer varieties have become ripe, bruising is difficult to prevent.

The softer varieties such as Ribston, Cox, and Jonathan are the most subject but many other varieties may be affected, especially in large fruits which were making rapid growth following heavy rains before picking and which are consequently very turgid with juice.

(f) Vascular breakdown and fleck

These are types of localized vascular breakdowns which finally merge into a general senescent breakdown (Carne and Martin 1938*a*).

(i) *Vascular breakdown.*—This has been found in varieties susceptible to low temperature breakdown which have been held too long in temperatures above the critical for that disorder. The pit-like lesions are relatively large and few, up to 5 mm. in diameter. They occur mainly in association with the core-line vasculars and may extend radially into the flesh. Vascular breakdowns appear first in the larger and more mature fruit stored at 36° to 40°F. Skin treatments and gas storage in oiled wraps retard ripening and delay vascular breakdown. This form is usually found in the harder varieties such as French Crab and Sturmer. It may be confused with brown heart.

(ii) *Fleck.*—This is a senescent form of vascular breakdown in varieties liable to low temperature breakdown, held too long at temperatures above the critical for that disorder. Minute brown spots, not pits, may show through the yellow skin and be mistaken for a form of storage pit. On cutting the apples it will be found that the flesh is mealy and in the later stages discoloured. The vasculars appear as dark brown streaks or flecks in the flesh. It has been mainly seen in storage experiments with Cox. Fleck may also develop in tissues which have recovered from watercore but have not regained their normal storage life (Carne and Martin 1934). Unlike pit the browned vasculars are not separated from the general flesh browning by a persistent whitish zone.

These disorders are of minor importance but are of interest in their possible confusion with pit and brown heart in over-stored fruit.

(g) Low temperature breakdown (Synonyms: Internal and soggy breakdowns, flesh collapse, &c.)

This type of breakdown (Figs. 44, 45) is liable to occur in many varieties grown in the cooler apple-growing areas of the world. It has been confused with other types in some of the alternative names given above. That adopted here was first used by Kidd in England (1928). In Australia the disorder is important in Tasmania (Carne and Martin 1935*b*), and Victoria (Trout, Tindale, and Huelin 1940).

Typically this breakdown starts as a light brown discolouration in the outer cortex, occasionally deeper, and away from the skin. It is often preceded or accompanied by late scald of the skin (Section 18). The discolouration of the flesh spreads inward and, at a slower rate, outward. It becomes darker but the advancing edges remain ill-defined and light coloured until they reach the core or skin. Only in very advanced cases is the core affected. In many varieties the affected flesh is wet and soggy and the fruit feels soft but resilient. In others, notably Jonathan, the flesh becomes mealy and soft and the affected fruits are not resilient. In others again, as in Cox, the flesh may be soggy or mealy according to the maturity of the fruit when affected. Late scald may be present and may start independently of the flesh browning but eventually becomes involved with it. It ranges from dark to almost black water-soaked areas on green skin to brown or honey-coloured areas on yellow skin. These areas are suggestive of deep scald (q.v.) but are less limited in extent and location and there is no depression of the surface. Many apples show no external evidence of this breakdown until it is in an advanced condition.

Low temperature breakdown frequently starts in the calyx half of the fruit but this is far from being the rule. Both it and late scald often start at the stem end of culinary varieties such as French Crab, Alfriston, and Crow Egg.

(i) *Factors Affecting Liability.*

Low temperature breakdown is confined to certain varieties stored at or below a critical temperature which varies with the variety, the climate in which it is grown, the size of the fruit and the crop from which it came, its maturity when placed in cool storage, and the duration of such storage. Further development ceases when the fruit is removed from cool storage, but senescent breakdown may follow.

In greater detail the factors influencing susceptibility include (Carne and Martin 1935*b*):

(1) *Variety.*—Varieties of moderate to high titratable acidity at harvest time are more susceptible than those of low acidity. Susceptible varieties include Cox, Ribston, Jonathan, Scarlet, French Crab, and Sturmer. Those of low susceptibility include Worcester, Crofton, Democrat, Delicious, and Granny Smith.

(2) *Seasonal temperature in the orchard.*—For all practical purposes this disorder is confined in Australia to Tasmanian and to a lesser extent to Victorian apples. Seasonal susceptibility varies greatly. Other things being similar there appears to be an association of

susceptibility with the average temperature four to eight weeks before the harvest. The lower the temperature the greater the susceptibility of the fruit.

(3) *Size of crop and fruit.*—Large fruits are more susceptible than smaller from the same tree, but there is an outstanding relation between susceptibility and the size of the crop on different trees in the same season. The smaller the crop as indicated by the average size of the fruit the greater the susceptibility (Carne and Martin 1938*b*). Light crop fruit is higher in acidity than heavy crop fruit.

(4) *Maturity of the fruit when stored.*—The relation of maturity to susceptibility is obscure. It is possible that after a certain stage susceptibility declines with maturity, but because successive pickings from the same trees tend to have an increasing average fruit size, the latter may mask the effect on maturity. In such cases the decline with maturity might not appear in storage experiments except in very late picks if at all. Unfortunately, reports of storage experiments have rarely recorded the average fruit size.

In 1929 (Carne *et al.* 1930) a breakdown in Dunns in Western Australia at 33°-34°F. showed a strong association with immaturity and was suspected to be a form of low temperature breakdown. If so, it is the only instance recorded from Western Australia.

(5) *Critical storage temperature.*—The critical temperature may vary between that causing freezing injury (about 28°F.) and 40°F. according to the susceptibility of the fruit and the length of storage. It is usually under 38° in commercial fruit.

(6) *Length of cool storage.*—Liability increases with the length of time low temperatures operate. Consequently the disorder is more common in long storage fruit in land stores than in fruit shipped overseas during the harvest season. Some varieties of low susceptibility may be affected by long cool storage, especially if other factors are favourable for breakdown. Such varieties include Cleopatra and Dunns, which are usually regarded as not suitable for long storage.

(7) *High CO_2 content in the storage air.*—This renders apples subject to low temperature injury. Gas storage of susceptible fruit requires relatively high storage temperatures.

(ii) *Control*

The control methods which follow are necessary only for susceptible varieties grown in cooler districts.

(1) For long storage, temperatures below 36°F. should not be used.

(2) Avoid light crop fruit for export or long cool storage.

(3) Provided fruit from good crops is shipped at a suitable stage of maturity no special action is necessary for export during the harvest season.

(4) Susceptible varieties like Cox and Ribston should not be stored at 32°-34°F. for more than 4 weeks for light crop fruit and 6-8 weeks for good crops.

(5) If it is desired to cool-store them, pick light crop Jonathan, Scarlet, French Crab, and Sturmer early and store at 36°-38°F. After 2 months withdraw samples of about 1 bushel of the largest size of each and hold at ordinary temperatures. Cut a proportion after a week to see how the fruit is standing up. Repeat this test about every 2 weeks while the fruit is in store.

(h) **Brown heart or carbon dioxide injury** (Synonyms: Aldehyde poisoning and breakdown)

This disorder (Smith 1924; Carne 1940) is caused by concentrations of CO_2 in the storage atmosphere in excess of a critical limit (usually 8-10 per cent.) determined by the variety, the temperature, and the maturity of the fruit. In practice it is commercially confined to insufficiently ventilated refrigerated holds of ships. It is not a problem in Australian cool stores but may become one with the introduction of gas storage (Huelin and Tindale 1947). Only in very advanced stages are there any external symptoms. Then the fruit may appear dull, dark, and water-injected. It will then have a resilient sponginess more pronounced than the soggy form of low temperature breakdown.

The internal lesions (Figs. 47, 48) start as dark brown watery areas in the core or in association with the larger vasculars of the core line and cortex. The lesions increase in size and may coalesce, forming dark defined watery patches. While some of the main core line vasculars or their branches are invariably affected, the core is not necessarily involved. Only in advanced cases is the outer cortex and skin involved. Development of lesions ceases when the affected apples are removed to normal air, or if the storage chamber is thoroughly ventilated. The lesions then slowly dry out and develop cavities which are usually characteristically lens-shaped.

(i) *Diagnosis*

A wide range of symptoms may be found including the following:

(1) Brown cavities in the flesh obviously associated with branches from the main core-line vasculars; or the core tissues browned and with or without cavities, the brown areas between the carpels being more or less fan-shaped; or the core and core line affected, with the browning extending into the flesh; or the flesh affected near the core line or midway between the core line and the skin; or the flesh and the core involved in a general injected breakdown.

(2) When developed at relatively high temperatures (over 40°F.) the affected tissues tend to be darker and more injected than at low temperatures (under 36°F.). Browning usually starts in

association with the vasculars of the core line and their branches in the cortex. The isolated lesions in the cortex extend and become confluent, forming a more or less continuous zone. This zone extends inwards and outwards. The core may be involved primarily, or by extension of the flesh lesions, but not infrequently shows little or no browning.

(3) When developed but not necessarily originated at low temperatures, the core (and more or less of the cortex) is normally involved. Lesions may also start in association with the mid-cortex vasculars. These lesions may become confluent and extend inward and outward. This may result in an outer brown zone separated from the brown core zone by a belt of apparently unaffected tissue. The lesions are usually lighter in colour and less injected than when formed at higher temperatures.

In brief, at low temperatures brown heart usually starts in or near the core and at higher temperatures at the core line or in the cortex.

Brown heart is darker, and more localized and defined than low temperature breakdown. It develops lens-shaped cavities and also may attack the core, both distinguishing it from the latter disorder. The core attack may differ from core flush in being darker and at first injected, and in developing cavities, but it is not always separable.

Diagnosis may be complicated when brown heart injury is accompanied by low temperature breakdown. The former takes only days (or hours) to be initiated and the latter weeks. Cases are known when brown heart has been caused within 30 hours of closing the hatches of refrigerated holds.

(ii) *Varietal Susceptibility*

Susceptibility is partly due to variety and partly due to the high CO_2 production of certain varieties. Thus certain varieties are peculiarly liable to cause trouble in insufficiently ventilated chambers because of the rapid accumulation of CO_2 when they predominate. Sturmer is notable in this respect. Other susceptible varieties include French Crab, Scarlet, Cleopatra, Cox, and Tasman's Pride. Jonathan, Granny Smith, Democrat, and Crofton have been rarely affected in shipments.

(iii) *Conditions Favouring Susceptibility*

These include late picking, forward maturity, light crop fruit, and delay between picking and cooling. The length of time required to cause injury depends on the CO_2 concentration; 5 per cent. may cause it in ten or more weeks and 10 per cent. in one week or less.

(iv) *Control*

Apples exported under refrigeration should be shipped in vessels equipped with means of determining the CO_2 concentrations of the air in the chambers, efficient means of ventilating, and rapid cooling capacity. The greatest danger period is that of high CO_2 production by the fruit, i.e., that before the fruit is cooled to carrying temperature. Pre-cooling before shipment will reduce the ship cooling period. Special care should be taken when a cargo consists largely of Sturmer apples.

The best modern systems of ship refrigeration have a high cooling capacity, high fan capacity (20-30 changes of air per hour), and cooling by means of air preferably drawn vertically through the cargo. With vertical air cooling no dunnage other than on the floor is needed. In some ships a further improvement is to take the air from the hold up sheathing wall ducts back to the battery. This serves to keep down heat leakage from outside the hold into the chambers through the insulation.

(i) Alcoholic or oxygen deficiency breakdown (Synonym: Alcoholic poisoning)

This rather rare disorder (Fig. 49) is usually found associated with brown heart in insufficiently ventilated ships' holds. It is due to a deficiency of oxygen resulting in anaerobic respiration and the development of alcohol (Thomas 1931). It can be produced experimentally in the absence of any accumulation of CO_2 by storing in nitrogen. In practice, however, the oxygen deficiency is due to it being used up by the fruit in respiration and the production of CO_2; hence its usual association with brown heart. It may be found alone in an apple or with brown heart. Apples in the same hold and of the same kind may have either one or the other disorder.

Description.—Affected apples exhibit dark water-soaked areas extending in from the skin. Externally, these are usually on the cheeks but may involve the calyx and stem basins. When the apples are removed from the chamber or the latter is ventilated sufficiently, the development of this breakdown ceases. If the affected flesh is fairly shallow it may then dry out and the skin above may become depressed in a manner resembling crinkle or deep scald. If the whole or greater part of the flesh is affected the apples remain turgid with a sponge-rubber resilience. In all cases the breakdown is, at least initially, of the soggy type.

Internally the symptoms range from the outer cortex water-soaked and dark, or the same tissues dry and light brown, to a dark water-soaking of the whole apple including the core. While still injected the flesh has a strong alcoholic smell and taste.

Alcoholic breakdown has only been found commercially in association with severe occurrences of brown heart and in the varieties Sturmer and French Crab, which are very susceptible to the latter disorder.

Separation from other disorders.—It is distinguished from low temperature breakdown by starting in the subepidermal tissues rather than the outer cortex, the affected tissues being darker and more defined, the marked presence of alcohol, and the fact that it does not require the low temperatures associated with that disorder.

It has been confused with deep scald (Carne and Martin 1935*a*; Kidd and West 1923; Thomas 1931) on external appearance only. It is distinguished by the continued development of the disorder as long as the causal atmosphere remains until the whole apple is involved, and it is not confined to the outer cortex as is deep scald. Other differences are the greater injection and darker colour of the flesh, the marked presence of alcohol, and the absence of the smooth surface depressions characteristic of deep scald.

From brown heart it is distinguished by its commencement in the outer cortex away from the main vasculars, the lighter colour of the dried out tissues, the strong development of alcohol, and the line of demarcation where the two disorders meet in an apple.

Control.—As for brown heart.

(j) **Heat scald** (Section 29)

Caused by intense sun heat or fires close to the trees. Common in fruit lying on soils which heat readily in the sun. The skin shows a dark water-soaked appearance. The underlying flesh is water-soaked and both skin and flesh rapidly become brown. The injury may be shallow or deep. Later the affected tissue may dry out and the surface become depressed and discoloured, or the fruit rots.

(k) **Freezing breakdown** (Fig. 52)

Apples of which a small part of the outer tissues have been frozen may recover when the temperatures are raised. General freezing is followed by breakdown when the fruit thaws. Externally, affected fruits may show no symptoms or may show a dark watery appearance as with low temperature breakdown and have a similar resilient feel. Internally, the first symptom is the presence of ice crystals in the flesh, readily detected by cutting, and a watery condition of the flesh. Freezing injury starts from the subepidermal tissue but may be much deeper and even involve whole apples. Usually it is most severe in the fruit nearest to the cooling elements or cold air inlets in refrigerated chambers. The affected flesh on thawing normally becomes waterlogged and rapidly discolours pinkish and finally brown. The flesh vasculars may show discolouration first. If the injected tissue is relatively shallow it may dry out and contract resulting in a crinkle-like scald (Fig. 51) of the skin. In more severe cases the apples become involved in a general breakdown. Sometimes on thawing the outer tissues recover and breakdown develops in the inner cortex or core.

The crinkle-like scald attributed to freezing has been noted in Tasman Pride, Worcester, Delicious, and Legana and the core injury in French Crab.

Freezing breakdown may be confused with other breakdowns which have an injected phase: in the dried-out form with crinkle and brown heart, and in the early stages with alcoholic breakdown. The presence of ice crystals and injected flesh and of the typical cone-shaped bruises (Section 9) of frozen fruit are aids to diagnosis of freezing as the primary cause of breakdown.

(l) **Core flush**

A faint pinkish or yellowish discolouration of the core tissue changing to light or moderately dark brown (Fig. 46). Frequently appears as arrowhead-shaped discoloured areas between the cartilaginous carpels. Rarely extends much beyond the core line. The affected tissue is dry and may ultimately develop cavities. Core flush is a form of senescent breakdown of over-stored apples which because of their variety or immaturity when picked are resistant to low temperature breakdown. Liability decreases with maturity.

Core flush is an indication that cool-stored fruit should be marketed. Frequently it precedes a general breakdown (over-maturity breakdown). In very immature fruit core flush may occur early in the cool storage life of the fruit, but the usual occurrence is after long storage. Defective ventilation in cool storage not enough to cause brown heart may hasten the onset of core flush.

Because of its general association with fruit picked in more or less immature condition, core flush is seen mainly in culinary and other varieties like Granny Smith which the market prefers with green skins. However, long-keeping red varieties like Yates and Democrat may be affected.

(m) Corky core (Section 32)

A core breakdown (Fig. 58) resembling core flush developed in apples suffering from boron deficiency.

(n) Crinkle (Section 13)

A breakdown of apples (Figs. 24, 25) affected with immaturity watercore. Occasionally developed in stored fruit. Crinkle-like disorders may follow alcoholic and freezing breakdowns.

(o) Deep scald (Synonyms: Jonathan scald, soft scald, and soft scald type of soggy breakdown)

A form of low temperature breakdown (Fig 50) found in a few varieties and limited to the outer cortex. The critical temperature approximates 37°F. There are two forms:

(i) A brown discolouration of parts of the skin and outer cortex to a depth of upwards of 1·5 cm., soft under pressure. Found mainly in Jonathan and King Cole.

(ii) A similar but shallower discolouration rarely to a depth exceeding 0·5 cm. and firm under pressure. Found in Dunns, Democrat, and Rome Beauty.

Both forms show brown, smooth, finally depressed, sharply defined surface lesions often large and frequently forming a more or less continuous band around the middle or calyx half of the fruit. They never involve the stem or calyx basins. The symptoms have been confused with those of alcoholic breakdown (Fig. 49).

Internally the lesions start in the outer cortex, but away from the skin, as shallow brown injected bruise-like areas running parallel with the surface (Carne and Martin 1935*a*). These lesions extend outward and laterally within the outer cortex and then cease to develop further as the fruit passes the critical stage of maturity. The brown flesh dries out, the skin turns brown and collapses. Once the internal lesions have started to develop at low temperatures they continue until fully developed, with characteristic surface symptoms at whatever temperature the fruit is then held. Consequently fruit after removal from cool store may appear to become affected, though the injury has its origin in the first month or two of cool storage. The affected apples are spoiled from a marketing point of view but are little affected for use.

Conditions favouring the disorder.—Susceptibility increases with the size of the fruit and delay in cooling, but the major factor, other than variety, is the size of the crop on the trees from which the fruit is taken. Light crop fruit is very susceptible and heavy crop hardly at all. Given susceptible fruit the incidence of deep scald is greatest when fruit at the optimum maturity for flavour development is stored at low temperatures (Trout *et al.* 1940). It is practically unknown at 38°-40°F. but at such temperatures the storage life is fairly short. Liability to deep scald increases as the temperature is reduced, especially below 36°. In this the reaction is similar to that for low temperature breakdown. In cool stores it is often associated with close proximity to cooling coils or inlet air ducts.

Control.—One difficulty arises from a popular demand for Jonathan apples about 2¾-in. diameter. An average size on the tree of 2¾ in. at normal picking time is definite evidence of a light crop, which is subject to deep scald and in the cooler climates to low temperature breakdown. Delayed picking to obtain increased size, means increased liability to over-maturity breakdown and other defects of senescence as well as deep scald.

All Jonathan trees carrying a crop averaging 2½ in. or larger about two weeks before the usual picking date should be clearly marked. Pick these trees first and finish picking before commencing on the heavier crops. Market the light crop fruit within about a week of picking or cool-store within 24 hours at 36-38°, and reduce the temperature each month by 2° until 32°-34° is reached. Inspect the fruit regularly by removing a few of the larger apples to ordinary temperatures to note how they behave after a few days. When marketing Jonathans ex cool store commence with the light crop fruit and the larger sizes of that fruit. For export or long storage use only the good crop fruit, average size on trees up to 2½ in., picked at the normal time. As a further precaution this fruit could be held at 34°-36° for a month before reducing the store temperature to 32°-34°.

The main essential is to keep the susceptible light crop fruit apart from the heavy crop fruit and to market it first. This is a great improvement on relating marketing to fruit size irrespective of the crop size.

The foregoing applies mainly to Jonathan and King Cole. In Dunns and Rome Beauty the safe average crop size would be indicated by about 2⅝ in. and Democrat by 2¾ in. at normal picking time.

Section 20. Unpleasant Flavours

(a) *Alcoholic Flavour*

An unpleasant alcoholic flavour may accompany a flesh condition ranging from firm and apparently normal, through watercore, to that of soggy breakdown. The flesh is rarely if ever mealy. Alcohol may be detected in:

(i) Apples with extensive *early watercore* (Section 11). In such cases the alcohol, which is usually not sufficient to cause an unpleasant flavour, is confined to the injected tissues.

(ii) Apples which have received excessive *skin treatments* (Section 31) with castor oil and shellac or oil emulsions and have been held at temperatures about 60°F. or higher, especially when more or less immature when treated.

(iii) Apples which have been *stored in atmospheres lacking sufficient oxygen.* This is found mainly in airtight storage in which the oxygen has been used up by respiration. Alcoholic breakdown (Section 19) finally develops. Both before and afterwards alcohol is very evident in the taste and odour.

(iv) Apples which have been fumigated with *hydrocyanic acid gas* (Section 31) some time previously.

(*b*) *Oil Flavour*

This is rare and has been recorded mainly in overseas shipments. It may be due to oil getting on the boxes during loading or to oil leakages in holds and even to the intake of exhaust fumes of motor vessels by the ventilation system. Open stacking of affected boxes in well ventilated sheds and other means of ventilating the affected fruit such as removing the paper wraps, are fairly effective in removing the oil flavour.

Section 21. Rots Following Non-parasitic Disorders

It is apt to be overlooked that most fungal rotting of apples follows some deterioration in the natural protection of the fruit against saprophytic fungi. Conditions permitting fungal invasion include injuries to the skin and in some cases the core, and the inability of open lenticels to exclude moisture and fungal invasion. Given the opportunity, fungal invasion increases with the temperature (within normal limits), the humidity of the air, and the maturity of the fruit. Large and especially light crop fruit are more susceptible to rots than smaller and heavy crop fruit.

An interesting point in relation to lenticel infection by rots arises in connexion with apples shipped to tropical climates under non-refrigerated conditions. Such apples should be picked at the stage of early maturity suitable for long cool storage. Varieties like Jonathan, Delicious, Cleopatra, and Yates, which ripen, become mealy, and lose flavour rapidly at ordinary temperatures, should be cool-stored before shipment unless they can be shipped within about two weeks of picking. Varieties like Granny Smith, French Crab, and Sturmer which do not deteriorate so rapidly can be held in common storage for longer periods before shipment, the time being limited mainly by the ground colour, especially in varieties of which markets prefer the colour to be definitely greenish. Holding in common storage of fruit picked at early maturity tends to reduce its liability to lenticel rots under tropical conditions. This is because open lenticels tend to become sealed off in common storage more than in cool storage (English, Ryall and Smith 1946). Cool-stored fruit passing into tropical conditions, especially when the transition is sudden, is liable to lenticel infection. It should, therefore be allowed a few days to warm up before shipment, provided always that the maturity is such that it will not deteriorate rapidly in other ways.

Once fungi have gained entry their rate of growth in the apple tissues increases with the maturity of the fruit or in other words with the concentration of soluble solids in the cell sap.

Defects disposing fruit to fungal rots include:

(*a*) *Mechanical injuries,* such as cuts, punctures, and bruises. These either expose the flesh or weaken the resistance of the skin to invasion.

(*b*) *Growth ruptures,* such as stem-end cracks, core and calyx-tube splits, and cracks following spray burn and other skin hardening.

(*c*) *Lenticel injuries,* such as are found in lenticel spots and caused by sprays, skin treatments, stem-end cracks, &c.

(*d*) *Calyx and stem-end injury,* following frost injury, skin blister, skin treatments, stem-end cracks, &c.

(*e*) *Skin softening,* due to scalds and breakdowns allowing easy rupture and even direct fungal invasion. Also *skin cracking* following mealy breakdown.

VIII. CAUSES OF DISORDERS

Section 22. Immaturity Disorders

For definition of Immaturity see Section 23.

Dessert apples are immature, if, when picked, they are unable to develop normal ripeness. Commercially, immature fruit may be considered sufficiently mature for cooking. Very immature culinary fruit is often marketed within a few days of picking. Very immature fruit will not ripen and rarely loses all the green of its ground colour. Less immature fruit will develop to a maturity which lacks the flesh texture and flavour of normal ripeness.

Immaturity renders some varieties liable to storage pit (Section 15) and superficial storage scald (Section 18). Immature fruit is very liable to wilt (Section 5) when stored. This is associated with its inability to develop the normal waxy bloom which reduces wilting in mature apples. Immature fruit is unsuitable for skin treatments (Section 31) designed to delay ripening as it is likely to develop an unpleasant alcoholic flavour and never ripens.

The increasing use of highly-coloured strains of dessert varieties is liable to lead to premature picking because of their early colouring. Correct picking times should be adhered to as ripening is not hastened by greater colour development. Such strains include Red Delicious (Lalla, &c.), Red Rome (Glengyle Red, &c.), Red Cox, Red Crofton, Red Statesman (Warrior, &c.), and Red Jonathan.

Section 23. Over-maturity Disorders

Dessert apples are mature for picking when they will develop normal ripeness. They are over-mature for picking for market when they have reached a stage when they will become full ripe before they can be retailed. They are over-mature for shipment or storage when they are unlikely to keep for a reasonable period for the variety under the conditions they will experience. It is therefore a matter of judgment what constitutes desirable maturity in each set of circumstances.

The safe commercial picking period for dessert fruit varies with the variety, the size of the crop, the climate, and the nature and length of storage. The early part of the period gives the maximum storage life and mid-period the best marketing fruit. The late period is suitable only for fruit for quick retail sale.

The terms immaturity, maturity, and over-maturity of apples have in themselves no specific meaning. They are at best relative terms which gain meaning when qualified by the purposes to which the apples are to be put. For instance, maturity for picking may represent three stages of maturity, the earliest for early sale for culinary purposes, the next for storage, and the most advanced for marketing within a few days as dessert fruit. The terminology here used is open to question (see Lott 1945). It is based more on commercial fruit usage than on botanical data.

It is of interest that no biologically satisfactory definition of apple maturity has been found. Maturity can be defined in relation to one or more of the following: ground colour, starch content, acidity and refractive index of the juice, &c., but not collectively with all as the changes in these do not necessarily parallel each other. While all the apples on a tree or on trees of the same variety carrying crops of similar size grown under similar conditions may pass through the same changes in a similar way this is not true for all apples of the same variety. For instance, light crop apples grown under the same conditions may show less advanced starch loss and a higher acidity than heavy crop apples with a similar ground colour. For the purpose of this publication the following loose definitions will service:

(*a*) *Maturity in Relation to Picking for Marketing*

(i) *Immaturity.*—Dessert apples are immature for picking when they will not develop the normal ripe flavour, juiciness, and texture, or will develop disorders such as pit and wilt if picked and held for a reasonable time only.

Culinary apples are immature for picking if they have not reached reasonable size, are too astringent, or will not keep a reasonable time free from wilt.

(ii) *Maturity.*—Dessert apples are mature for picking when they will develop normal ripeness free from pit or wilt during a reasonable period of marketing or storage and marketing.

Culinary apples are mature for picking if they have reached sufficient size and will remain in an unripe condition during a reasonable period of marketing or storage and marketing without developing either pit or wilt.

Maturity for long storage is an earlier stage than maturity for marketing after short storage.

(iii) *Over-maturity.*—Dessert apples are over-mature for picking when they are ripe or so advanced that they will not keep in good condition during marketing, both wholesale and retail.

Culinary apples are over-mature for picking when the ground colour is definitely yellow or the flesh shows signs of becoming dry or mealy.

(*b*) *Maturity in Relation to Early Use from either Tree or Store*

(i) *Dessert apples.*—These are:

Immature when they are too hard, acid, or astringent for most consumers.

Mature when they have developed in appearance, aroma, flavour, and juiciness the condition known as ripeness. The acidity varies with the variety but sugar is always well developed.

Over-mature when the juice content and flavour have declined, and the flesh has become mealy.

(ii) *Culinary apples.*—These are:

Immature when too small, hard, or astringent.

Mature when of sufficient size and the ground colour still green.

Over-mature when the flesh is mealy, dry, and liable to break up when machine-handled as with mechanical peelers.

(*c*) *General*

Dessert apples, particularly from light crops, may be picked at too early a maturity for dessert purposes if intended to be sold quickly for cooking. Large Jonathans are often so used.

Dual purpose varieties, such as Rome Beauty and Sturmer, are usually picked as dessert fruit but large sizes may be picked early for culinary purposes.

Culinary varieties are picked as early as possible consistent with large size. The objective is to obtain the longest storage life without ripening. For this reason and the market preference for a green ground colour, most culinary varieties have characteristically large fruits with a marked freedom from defects due to immaturity. Some are pit-liable but are usually picked before liability commences. They are not as a rule varieties of high dessert quality when allowed to reach dessert maturity.

The use of hormone sprays to reduce the loss of fruit by windfalls creates the danger of holding the fruit too long on the tree. The normal picking times should be adhered to as the spray does not delay ripening.

Defects of over-maturity include: (i) Poor quality and condition for marketing. (ii) Increasing tendency to bruise (Section 9, 24) and develop rots (Section 21). (iii) Increasing tendency to develop late watercore (Section 11) and senescent breakdown (Section 19).

Section 24. Handling Injuries

(*a*) *Bruising*

The most widespread defect of apples is undoubtedly bruising. Except in small consumer packages some bruising of dessert apples is inevitable in all but immature fruit and certain very hard varieties, but it should not be sufficient to affect the keeping quality or selling value. Liability to bruising increases with the maturity and size of the fruit. It varies between varieties, being greatest in those known as soft varieties such as Jonathan and those of irregular or ridged shapes such as Delicious, London Pippin, and Sturmer. It is greater for the fruit of light crops than for heavy crops of the same variety. Fruit which has made rapid growth during the few weeks preceding picking, following rain after drought, is the most susceptible to serious bruising. Bruising of immature fruit affects its appearance, while that of mature fruit also renders it more subject to breakdown and fungal rots. Large sappy fruit is particularly liable to rapid wastage when bruised. The more mature the fruit the more carefully it should be handled. Forward fruit is best marketed in open boxes.

Bruising is likely to occur at every stage of movement in the chain of events from the tree to the retail buyer. Such stages include:

(i) *Falling to ground.*—This may occur naturally or in the course of picking. The growing use of hormones to check windfalls of susceptible varieties is an effective remedy for the former. Delayed picking especially of short-stemmed clustered varieties such as Jonathan and Yates increases dropping due to overcrowding. Thinning and picking at the correct time reduce these losses and improve the quality of the fruit. Fallen fruit is almost inevitably bruised unless the ground is strawed to prevent it as is sometimes practised with Gravenstein.

(ii) *Picking.*—Bruising may be caused by the overfilling of picking bags, bumping of picking bags against ladders, dirt and rubbish in picking buckets or boxes, and careless filling of picking boxes. Excessive pressure of the fingers may cause bruising, and long finger nails may cause marking and even cutting of the skin. Overfilling of picking boxes makes bruising inevitable if the boxes are stacked.

(iii) *Carting.*—Poor stacking of picking and packed boxes on vehicles, rough tracks, careless driving, and excessive speed around corners are potential causes of bruising.

(iv) *Grading, or more correctly sizing.*—Incorrect speed adjustments for roller type graders, especially for irregular shaped varieties like London Pippin, Delicious, and Sturmer; dirt and projections preventing the smooth running of the fruit; and excessive drop to bins, may cause bruising.

(v) *Packing.*—Causes of bruising include packing too high in the box for lidding, especially at the ends; packing too loosely so that the fruit can move when the lidded box is handled; insufficient protection with wraps and protective strawboards or wood wool, &c.; wrapping the stalks of long-stemmed varieties against the fruit.

(vi) *Weak boxes.*—Badly made boxes and/or lack of wiring may lead to breakages of boxes and spilling of the fruit, during the loading and discharge of ships. Although the broken boxes are repacked and coopered much of the fruit is inevitably bruised.

(vii) *Rough handling of packed boxes.*—This occurs mainly in the loading and discharge of road vehicles, rail trucks, barges, and ships. Outstanding instances are the dropping and throwing of boxes; careless building of stacks which fall over; packing bulged boxes on the bulge; avoidable walking on boxes;

the use of boxes as supports for loading trays, gravity rollers, and slides; the use of boxes as bumpers at the bottom of slides; and stacking boxes on loading trays so that sling cables bear on bulged tops, &c.

(*b*) *Abrasions, Scratches, Cuts, and Punctures*

These are generally more serious than bruises because they provide ready entrance for rotting fungi. Fortunately they are far less common.

(i) *Abrasions.*—These are mainly due to overhigh packing, especially at the ends, and the use of rough box timber. In lidding, the fruits against the ends may become abraded. Lack of protective liners may cause abrasions against the box sides.

(ii) *Scratches and cuts.*—These are mainly caused by defects in the grading machine, splintered and warped box wood, and projecting nails.

(iii) *Punctures.*—These are usually due to careless nailing of box lids and wrapping the stalks of long-stemmed varieties against the fruit.

Section 25. Wind Injuries

Wind injury takes several forms.

(*a*) *Rub Marks, Scratches, Bruises, and Cuts.*

These may be caused when fruit is windblown into contact with stems, spurs, pruning stubs, and even leaves. An unusual variant on long-stemmed varieties has been noted after the passage through orchards of strong winds and the small cyclonic windstorms known as willie-willies or dust devils. It consists of narrow bruises forming regular figures—circles, 8's and S's—and passing into cuts in the worst cases.

(*b*) *Loss of Moisture*

Loss of moisture may result in:

(i) *Poor setting.*—Hot dry winds at flowering time may cause injury to the sex organs resulting in poor fertilization. The result is a poor set and asymmetrical fruit.

(ii) *Fruit wilting.*—Caused by excessive loss of water during hot dry winds. The loss of water is partly due to direct transpiration from the fruit but mainly to excessive transpiration from the leaves. If the leaves lose water faster than they can replace it from the trees they tend to draw on the fruit. This results from the higher osmotic tension of the leaf sap as compared with that of immature fruit (Carne *et al.* 1931, p. 47).

(iii) *Tree pit* (Section 14).—Loss of water as in (ii) above from maturing fruits of susceptible varieties is probably a major cause of tree pit (Carne *et al.* 1931).

Section 26. Hail Injuries

Hail injury ranges from small pit-like bruises, through punctures and irregular cuts, to large wounds caused by the flesh being cut right away even to the extent of exposing the seeds. Usually it can be recognized as minute to fairly large pitted spots rarely exceeding ½ in. in diameter. They are frequently clustered, especially if small, on the exposed portions of the fruits as they hung on the tree at the time of causation. Of course, the position of fruit often changes with its increasing weight and the relation of the spots to the direction from which the hail came may not be obvious at a later date.

If the fruit is badly affected when young it may become misshapen with growth. The skin is broken only in the case of severe injury. Such injuries are liable to rot infection in mature fruit. In immature, they usually heal but are unsightly. The flesh immediately beneath the hail-pitted areas becomes brown as with any other type of bruise. Small hail marks may be confused with pit. Distinguishing features are: they are not consistently associated with the calyx half of the fruit; there are no isolated lesions in the flesh away from the skin; the skin may be broken.

Section 27. Frost and Freezing Injuries

(*a*) *Frost Injuries*

Frost injury is most likely to occur during the period of blossoming and early fruit growth in October and November. In general the later the frosts the more superficial the damage. Forms of frost injury include:

(i) *Poor setting and malformed fruit.*—Frost may kill the pistils of the flowers and the seed embryos of the young fruit. In the former case the flowers fall and in the latter fruit development ceases and the fruits fall. If only some of the five styles of each pistil or some of the seed embryos are affected, fruits may develop but are usually malformed.

(ii) *Frost crack.*—Badly frosted very young fruits may develop longitudinal cracks extending into the vasculars of the core line. These may be connected by lateral cracks. Provided the fruit does not fall, subsequent growth results in surface grooves and depressions with brown corky tissue at the base. These may divide the surface into segments like those of a peeled mandarin.

(iii) *Frost dimple.*—This is of similar origin to frost crack but is limited to pitted or dimpled depressions with corky tissue at the base. It may not be distinguishable from other forms of dimple (Section 16) in the absence of other evidence of frost injury, especially when the corky areas are very minute.

(iv) *Frost band or russet.*—This is a rough or scabby russet often tending to form a band more or less around the calyx end of the fruit, but not extending into the calyx basin (Fig. 4). Restriction of growth under the russeted surface results in fruit becoming depressed on one side, or developing a pearmain-like neck. With continued growth of the fruit, the russeted areas may develop cracks. The absence of russet in and immediately around the calyx basin is probably due to the protection given by the flower parts during the frost period.

(v) *Abnormal shapes.*—In addition to that caused by frost band, there are other effects on shape resulting from frost injury. The calyx basin is often widened and the affected fruits are shorter in relation to width than is normal. Calyx crown depressions may be deepened and lobes may develop on fruit normally smooth topped. Asymmetrical one-sided growth is not uncommon as a result of the killing of the seed embryos in some carpels. The segments with seeds make more growth than those without.

(vi) *Calyx injury.*—This may be found in the death of the skin in the calyx basin, of the tissues around the calyx tube, and of the vasculars extending from the tube into the fruit. The dead skin in the basin may crack away in a circle exposing brown corky tissue underneath.

(vii) *Vascular injury.*—Fruits showing abnormal shapes and calyx injury and others showing little or no external evidence may show vascular injury on cutting. The vasculars leading from the calyx tube to the core line then show browning often extending deep into the fruit (Thomas 1934). Sometimes the browning extends into the flesh.

(viii) *Persistent chlorophyll.*—This has been found associated with abnormal shapes and calyx injury in Sturmer. The skin of the calyx lobes failed to change from green to yellow in keeping with the rest of the fruit surface.

(*b*) *Freezing Injuries*

(i) *Freezing injury in cool storage.*—Apples may be frozen if too near to cooling pipes, or to inlet ducts of air-cooled stores when the air temperature is below 28°F. If only slightly affected apples may recover, especially when slowly thawed, but some loss of storage life must be expected. If freezing is more severe the tissues are killed and freezing breakdown (Section 19) follows thawing. Ice crystals in the flesh, a water-soaked appearance of the flesh and skin, browned vasculars, and characteristic deep bruises (Section 9), as well as a general breakdown are features of freezing and freezing injury.

(ii) *Freezing scald* (Fig. 51).—This is a superficial form of breakdown attributed to severe freezing of short duration but lacking experimental confirmation. It consists of dark brown, slightly sunken, irregular blotches on the surface, usually on one side of an apple. The depressions frequently leave single, or groups of, lenticels isolated on islands of normal colour. It appears to affect non-flushed surfaces more than red, but the latter are not exempt. Though usually on the cheeks, the blotches may involve the calyx and stem basins. Though shallow and affecting only the epidermal tissues they make the surface rough to touch. A lighter-coloured typical superficial scald may accompany the blotches.

This disorder has been noted on Worcester, Tasman's Pride, Delicious, and Legana from both land and ship cool storage. These are all low acid varieties. Freezing scald has similarities with forms of crinkle (Section 13), alcoholic breakdown (Section 19) and light-induced scald (Section 18).

Section 28. Drought or Moisture-deficiency Injuries

Drought injury may be caused by (i) a deficiency of soil moisture due to insufficient rain or irrigation to keep the tree supplied, (ii) an excessive salt content of the soil moisture preventing a normal intake and causing root injury, (iii) excessive transpiration from the leaves which in turn compete for water with, and even withdraw it from, the fruit, and (iv) root injury caused mechanically, by disease, waterlogging of soil, &c. Drought conditions may operate over long periods of weeks, or short periods of hours to a few days during heat waves. The former results in small fruit but rarely in direct injuries, while the latter may cause injury, especially to fruits of normal to large size. Drought injury includes:

(*a*) *Continuous Drought*

(i) *Boron deficiency* (Section 32).—In soils in which boron deficiency is marginal, cork and associated disorders are usually confined to seasons of below normal moisture. Soils which dry out readily are more subject than deeper soils of the same type.

(ii) *Calyx-end injury and cracking* (Section 8).—This may be associated with dry soil conditions, or physiological droughts due to root injury. The tissues in the calyx basin die, become hard and dry, and may crack as the fruit grows.

(*b*) *Heat Wave Conditions*

(i) *Wilting* (Section 5).—Hot dry winds may cause such a loss of water from fruits still on the tree as to cause wilting. This loss is due mainly to the leaves withdrawing water from immature fruits when their own loss by transpiration is greater than they can offset by supplies from the roots.

(ii) *Tree pitting* (Section 14).—Serious loss of water from maturing fruits of pit-susceptible varieties leads more to pitting than wilting. The shortage of water instead of being general is concentrated in the tissues of lowest osmotic tension. These are those closest to the vasculars where the conversion of starch to sugar is least advanced.

Section 29. Heat and High-temperature Injuries

Apples may suffer from low temperatures in the spring causing frost injury (Section 27); insufficiently low temperatures in the winter causing delayed foliation, prolonged blossoming, and poor setting; and excessive temperatures causing heat injury to the fruit in the summer.

Liability to heat injury varies with varieties. In the cooler apple-growing areas of Australia practically all varieties may be grown, but red varieties frequently tend to lack colour. In warmer areas colour tends to be better but some varieties do not do so well. In the hotter apple areas red varieties tend to be too densely coloured or the colour becomes bleached and the successful varieties are still fewer. In general, the higher the temperature the less likely are the more acid varieties to succed, either through their liability to heat and moisture deficiency injuries or to their quick maturity and short storage life. It is no accident that while the medium to low acid varieties Jonathan, Cleopatra, Granny Smith, and Democrat are grown in all States, the high acid varieties like Sturmer, Cox, and Scarlet are practically confined to Tasmania. Granny Smith is at its best in New South Wales and Western Australia, while Jonathans in southern Victoria and northern Tasmania have a storage life and a colour superior to those from southern Tasmania and the warmer areas of the mainland. A few high acid varieties like Rokewood succeed in the warmer areas. This fact may be related to their late maturity.

It should be noted that heat injury is not so much caused by continuous high temperatures as by a sudden marked rise in temperature above that previously experienced by the fruit. There are two causes of such contrasting temperatures.

(i) The exposure to direct sunlight of fruit previously protected by the shading of foliage during the hotter hours of the day. This may be brought about by defoliation caused by accident, insect attack, spray injury, &c., but usually by the bending or breaking of branches with the increasing weight of growing fruit.

(ii) The occurrence of heat waves and bush fires, i.e. a sudden rise in temperature usually, but not necessarily, accompanied by strong dry winds. The sudden increase of temperatures lasting one to four days may be of the order of 20°F. or more above those previously prevailing. The greater the rise the greater the risk of damage. Provided the summer temperatures rise steadily, apples are rarely affected by high temperatures except in the case of watercore and consequent disorders in light crops.

(*a*) *Sunburn*

This is mainly due to heat waves or to the exposure to direct sunlight of fruit which was previously sheltered by leaves. The greatest damage is done by heat waves on trees of which the branches have become weighed down by the crop. Red varieties are less subject than others, and blushed surfaces than unblushed. Sunburn becomes darker in cool-stored apples and may be mistaken for superficial scald. Normally sunburn affects only the skin and a thin layer of underlying flesh. In bad cases it may go deeper but usually less than 0·3 cm. The skin becomes bleached (yellowish instead of green or red), brown or almost black, and hardened. The damaged surface may crack with the growth of the fruit or it may cause a growth restriction resulting in asymmetrical growth.

Fruit with watercore close to the surface is particularly subject to sunburn (Fig. 26). The injury is deeper and may show a range of symptoms passing from sunburn through sunscald into crinkle. In severe cases the fruit develops the depressed areas of crinkle with the brown skin of sunburn.

Severe sunburn may be produced on the upper layer of apples in orchard boxes exposed to direct sunlight on a hot day in the orchard. Occasionally sunburn may be found on low hung fruit not exposed to direct sunlight and caused by radiation of heat from light coloured soils which heat readily.

An interesting case in relation to sunburn came to light in an experiment to protect apple trees from hot easterly winds in Western Australia. Each was enclosed in high hessian walls. The result was a marked increase in sunburn. It was found necessary to have the walls on the east side only so as to permit freedom of air movement through the trees. Spraying during very hot days stimulates heat injury to the fruit and particularly the leaves. Fruit burn after sulphur spraying or dusting may be severe, especially on non-flushed varieties.

(*b*) *Heat Scald*

This is a more severe and deeper injury than sunburn. It may occur during exceptional heat waves as when the temperature exceeds about 110°F. in the shade or as a result of bush or other fires near the trees. It is very common in fruit lying on soils which have become very hot in the sun. The high air temperature effect has been noted in apples grown under irrigation at a pumping station on the Kalgoorlie water pipe line well outside the fruit-growing areas.

The early symptoms are a watersoaking of the flesh which rapidly turns brown. The skin may show sunburn but if not it appears dark and watersoaked. At this stage the affected fruit resembles apples in the early stages of baking in an oven. The whole or only part of the fruit may be affected. In the later stages the affected flesh dries out and shrinks or the whole fruit breaks down and becomes subject to rots.

(*c*) *Early or Immaturity Watercore* (Section 11)

This is a heat disorder (Fig. 23) to which immature light crop fruits are subject, especially when exposed to direct sunlight as are those towards the ends of leaders and laterals. In good crops it is usually rare and then only following heat waves. It is sometimes found on fruit on the underside of trees, especially on light coloured soils which heat readily on hot days.

Varietal susceptibility to this watercore varies greatly. It resembles the early stages of heat scald but differs usually in starting not just below the skin but deep in the tissues, particularly in the core or in association with the main vasculars. In exceptional heat waves (110°F. and over in the shade), however, it has been noted developing just beneath the skin and not extending in more than 0·5 cm.

Immaturity watercore may be induced by directing heat on to immature fruit on the tree.

(*d*) *Crinkle* (Section 13)

This is an irregular depression (Figs. 23-25) of the surface of apples, overlying a usually shallow layer of dried-out dead tissue. It is a sequence to immaturity watercore especially when the temperatures which caused the latter are followed by another heat wave. Occasionally crinkle may develop in watercored apples in cool storage.

Section 30. Light-induced Scald

Injury to apples exposed to light (Hockey 1932) is confined to fruit which has reached the full mature yellow or cream of ripe fruit or nearly so. It should not be confused with heat injury caused by direct exposure to sun heat during the warmer months. The disorder takes two forms.

(*a*) *Diffused Scald*

A dirty-looking brown general discolouration (Fig. 37) of the yellow surface of fruit left hanging on the trees long after the normal picking time, particularly of late varieties left on the trees into June or later and of apples exposed to strong sunlight in picking boxes or in shop windows. The lenticels in particular become dark. Many varieties are subject, including Cleopatra, Sturmer, Delicious, and Golden Delicious. The name orchard scald has been applied to this form when found on fruit still on the tree (Section 18).

(*b*) *Severe Scald*

Sharply defined brown sunken irregular areas (Fig. 40) on apples ex cool store, exposed to direct sunlight in shop windows, especially when placed close to the glass. Noted on Cleopatra and to a lesser extent on Sturmer and poorly coloured Delicious.

Red surfaces are not affected. Non-flushed apples are more subject than red or partially flushed. The general browning is the more common and has been noted in window displays of Australian Cleopatra in London. The defined type has occasionally been seen in shops in Australia.

Section 31. Chemical Injuries

This section covers apple injuries caused by the use of fungicides and insecticides and treatments for the removal of their residues from fruits; and other chemical causes.

(*a*) *Sunburn*

Sprays of any kind, even of water, applied during very hot sunny weather are apt to result in the sunburning of apples (Section 29).

(*b*) *Copper Russet and Spray Burn*

This may result from the use of Bordeaux mixture and other copper-containing fungicides when used on trees after the green tip stage and before the fruit has been harvested. Susceptibility to injury declines somewhat as the fruit matures.

The symptoms (Fig. 5) vary from a slight russeting of the skin and corking of the lenticels to a condition (spray burn) in which the skin and subepidermal tissues are killed, and the affected areas become hard and dark in colour. The affected surfaces in bad cases become rough and may crack as the fruits grow. Because it usually receives the more spray, the calyx half of the fruit is more subject to injury than the stem half. The calyx basin is consequently more likely to be affected than the stem basin. As natural russet usually occurs in and around the latter the occurrence of russet not associated with the stem end usually indicates spray injury. The presence of russet streaks such as might be caused by the running down of spray drops is another guide to diagnosis. When the russet passes into a continuous rough dark area (spray burn) the commercial effect is important even on the russet varieties now seldom grown. Natural russet cracking when present is usually more or less in and around the stem basin, while spray-burn cracking is irregular and usually on the cheeks of the fruit.

A limited amount of spray-russet, provided it is not rough or dark in colour, is usually permissible in market fruit according to grade. The degrading effect is greater on green and yellow dessert varieties and less on well coloured red varieties or culinary apples. Apples with spray burn have little or no value for marketing fresh.

Spray burn and heavy russeting may lead to asymmetrical growth and certainly lead to premature wilting when the fruit is stored. This wilting occurs in the flesh under the russeted skin long before the rest of an apple is affected. The flesh beneath the russet tends to be higher in flavour and acidity than the rest of the apple. This probably explains an often claimed preference for russeted apples by individuals. Nevertheless the general public demand, so responsive to eye appeal, is for non-russeted clean skinned apples. Premature wilting is associated with the destruction of the cuticle and the inability of the injured skin to develop the normal waxy bloom.

Varieties very susceptible to copper spray russet include Sturmer, Cox, Jonathan, Gravenstein, Cleopatra, Granny Smith, London Pippin, Rokewood, Dunns, and Yates. Danger of injury is reduced if correctly made sprays used at the right strength are applied in bright warm (but not very hot) dry weather. Reasonably quick drying of the spray is desirable. Injury is increased in dull humid slow-drying, and in very hot, weather, and by incorrectly mixed or over-strong sprays.

(*c*) *Sulphur Injury*

This is a form of sunburn which may follow the use of sulphur applied to the trees either as a dust or as a spray (lime-sulphur, colloidal sulphur, &c.) during or just before hot sunny weather. In general the injury to the fruit is slight and appears as a russeting, bronzing, or light browning. In severe cases the affected skin may become dark brown and leathery. With very young fruit the skin may become hard and dry resulting in malformed growth or cracking (Farrell 1924) though such fruit usually falls. Excessive spray strengths and very hot weather at spraying time should be avoided, especially with susceptible varieties such as Scarlet and non-flushed varieties such as Granny Smith, Golden Delicious, and Cleopatra.

(*d*) *Summer Oil Spray Injury*

This may take several forms:

(i) *Oil spray stain.*—Light to dark brown discolouration, often most marked in and around the calyx basin or in streaks running down the cheeks. Sometimes called russeting but the minute cracking of the cuticle characteristic of true russet is absent. Occurs mainly when summer oils are applied during hot weather. Red skin is less liable to injury than green. Cleopatra is subject to this stain.

(ii) *Lenticel oil injury.*—The lenticels become enlarged and corky and several may become involved in a brown corky spot. These spots may not be visible when the fruit is picked and only become apparent after the fruit has been held in storage. This spotting may be increased if the trees are suffering from drought when sprayed. It has been noted on Jonathan and Rome Beauty.

(iii) *Oil spot.*—This is a persistent oily blotch in the skin of apples. On green surfaces, these spots tend to remain green when the remainder has turned yellow. This has been noted mainly on Granny Smith.

(e) *Arsenical Spray Injury* (Arsenical Spotting)

This occurs as irregular or crescent-shaped brown, black, or purple superficial depressed spots on the fruit, frequently in the calyx and stem depressions. It is caused by free soluble arsenic. Commercial arsenical spray preparations can usually be relied upon to be free from soluble arsenic but it may be formed following the use of unsuitable water in making up the spray or the use of soap as a spreader for a combination of lead arsenate and lime-sulphur. Less frequently it may be due to the combination of lead arsenate and summer white oil emulsions. It may also follow the use of white oil on apples carrying heavy arsenical residues. Safety precautions include the avoidance of alkaline waters and not spraying during very hot or humid days. Bright dry warm days are desirable.

(f) *Green Timber Injury*

(i) *Karri injury.*—Karri (*Eucalyptus diversicolor*) in Western Australia gives off acid (acetic) vapours which affect fruits in boxes of freshly cut green timber. It causes a brown spotted or general scald. Most of the scald starts at points where the skin has been injured by insects, fungi, bruises, &c. Symptomatically this disorder is very similar to severe light-induced scald (Fig. 40). The acid fumes come from the sap in the timber and are lost as the timber dries. The obvious prevention is to use seasoned or at least reasonably dry boxes.

(ii) *Cypress injury.*—A brown skin scald similar to karri injury but less spotted is caused when apples are packed in freshly sawn green timber of the commonly cultivated cypress pine (*Cupressus macrocarpa*). The strawboard liners and fruit wraps become impregnated with the resinous odour of the timber. In a case noted in Tasmania the resultant scald first appeared on the fruit nearest the wood but later became general.

(g) *Injury Caused by Acid Treatments to Remove Arsenical Spray Residues*

Acid baths to remove excessive arsenical residues are rarely used in Australia. The need for them has been largely overcome by spray schedules for codling moth which substitute summer oils for arsenicals in the later cover sprays, or by the use of DDT.

The acid treatment when used usually involves dipping the fruit into 1 per cent. hydrochloric acid in water at 70°–80°F., followed by thorough washing. The objections to the treatment are:

(1) It is unsuitable for varieties with open calyx tubes (Section 7) such as Cleopatra, London Pippin, Newtown Pippin, and Delicious, owing to the danger of core rots.

(2) It may cause skin injury to the fruit if the acid bath is too strong or its temperature too high, and if the washing is not thorough or the water not changed frequently enough to prevent accumulation of dissolved arsenic.

The injuries (Bryden and Hall 1946) are rather slow in developing and are usually first seen when the treated fruit is removed from cool storage. There are three main types:

(i) *Calyx or stem-end injury.*—The skin in and around the calyx and stem cavities may become grey to dark-brown or black. The dead skin becomes dry and may crack and lift away from the flesh which develops a corky protection, or the affected tissue may be invaded by rots. The darker injury is attributed to arsenic and the lighter to acid, but both may operate together.

(ii) *Lenticel spots and scald.*—A skin injury ranging from pale to brown indefinite areas or brown or black spots, sometimes sunken. It occurs anywhere on a fruit but mainly towards the calyx and stem ends. May be confused with superficial storage and spot scalds. The spots usually appear to originate at the lenticels. The black spots are attributed to arsenic and the light discolouration to acid.

(iii) *Core injury.*—Varieties with open cores, if submerged too deeply or too long in the acid bath, are liable to be damaged internally. The acid penetrates the calyx tube and even the core, causing death of the surrounding tissues which become very subject to fungal rots. Cases have been noted of apparently sound Cleopatras and Yellow Newtowns rapidly developing core rots on removal from cool storage, and becoming useless in a few days. Delicious and London Pippin are also very liable to this injury.

The disorder can readily be confused with mouldy core (Section 7) but examination of a series of specimens from the same line of fruit may disclose brown tissue in the calyx basin and tube or even the stem basin. Mouldy core on the other hand usually starts at the calyx end of the core.

(*h*) *Injuries Caused by Skin Treatments to Prolong Storage Life*

Wax and oil emulsions and mixtures of shellac and castor oil (in alcohol) have been used as dips or sprays to prevent wilting and reduce respiration and thus increase the effective storage life of apples for marketing. The following defects have been noted:

(i) *Browning and injury to the skin following slow drying.*—This occurs mainly in the calyx and stem basins and where the wet fruits have been in contact. The browned skin is subject to fungal rots.

(ii) *Lenticel spotting.*—This is due to penetration of and the death of tissue beneath the lenticels or skin injuries. The spots are subject to fungal rots.

(iii) *Alcoholic flavour and breakdown* (Section 19).—Treatments which too drastically reduce diffusion of air into and respiratory gases out from the fruit result in anaerobic respiration (fermentation) of the fruit. This results in an unpleasant alcoholic flavour which may be followed by a soggy breakdown. This is particularly likely in immature fruit held at temperatures of 65°F. or over.

(iv) *Failure of green skin to change to yellow.*—Skin treatments which check respiration also check the normal change of the green skin to yellow. If respiration is checked too much as in (iii) the ground colour of the fruit may never change to yellow and the flesh may never ripen normally. This, though no objection in culinary apples, is a defect in dessert fruit.

(*i*) *Fruit Injuries Caused by Blossom-killing Sprays*

Cresylic acid, tar distillate, and DNC sprays used to thin or remove blossoms vary in effectiveness with the variety, strength of spray, time of spraying, &c. If used in insufficient strength or too late a proportion of the blossoms will set fruit, much of which may be malformed by defective seed development or direct injury to the young fruits.

(*j*) *Fruit Injury from Fumigation*

Fumigation of fresh apples is rare in Australia. It is reported from South Africa and U.S.A. that methyl bromide at the rate of 2 lb. per 1,000 cu. ft. caused injury after 6 hours' fumigation in most varieties tried and even in 2 hours with some. Susceptible varieties include Delicious and Granny Smith.

In 1945 a consignment of Granny Smith apples shipped in an ordinary hold from Western Australia to Victoria became contaminated by mites from a consignment of hay in the same hold. The apples were not affected, but discharge was delayed because the mite attacked the waterside workers. Tests of fumigation were made with carbon bisulphide and hydrocyanic acid gas without apparent injury to the fruit. Fruit treated with the latter gas for 3 hours, however, had developed a slight alcoholic flavour after 10 days, and after 20 days it was inedible though still normal in appearance.

(*k*) *Injury due to Excessive Carbon Dioxide in Storage Air* (Section 19)

Excessive carbon dioxide in the storage air may result from insufficient ventilation especially in warm store rooms or ships' holds or even in cool stores and refrigerated holds. The result is breakdown of the fruit, particularly that form known as brown heart.

(*l*) *Ripe Apple Injury in Stores*

Insufficient ventilation in stores in which a proportion of the apples are ripe may result in the ripening of and the development of lenticel storage spots (Section 18) on other apples (Kidd and West 1938). This may be due to the ethylene given off by ripe apples.

Section 32. Boron Deficiency Disorders (Cork)

The apple fruit disorders associated with a deficiency of available boron in the soil have received many names ranging from drought spot to bitter pit. These names are misleading in that they associate disorders of varied origin. For simplicity the term " cork ", first used by Mix (1916) for one of the forms, or alternatively the adjective " corky ", is here used to indicate that a disorder is due to boron deficiency.

(*a*) *Classification*

The following classification proposed by the writer is generally recognized:

(i) *Superficial cork.*—This has often been called " drought spot " though not primarily due to drought. Superficial cork may originate in apples from shortly after setting until about one-quarter grown, i.e. from late October to November. The first evidence is a watersoaked appearance of the surface tissues which may be accompanied by the exudation of sticky sap. This has a close resemblance externally to severe immaturity watercore which may follow heat waves from December to February (Section 11). The injected stage is followed by a browning and death of the epidermal tissues and finally by dark brown to black irregular depressed areas (Fig. 53). Fruit so affected falls prematurely. In less severe cases the fruit may become generally discoloured, rough and hard, and subsequently crack.

Superficial cork is relatively rare in boron-deficient areas in Australia and then usually when soil moisture is deficient in the spring.

(ii) *Cork.*—This form (Figs. 54, 55) affects the subepidermal tissues and may be recognized as slightly raised lumps each usually at the base of a surface depression. They are at first red or green on red, and dark green on green surfaces but may become brown. The surface of a lump may be sloughed off exposing brown corky tissue beneath. The internal lesions start as water-injected spots close to and sometimes involving the skin. Like the surface lumps the lesions are rounded and usually 3-5 mm. in diameter. They become dark brown to greenish black, with a persistent greenish border in the flesh. This greenish border may even show on red surfaces.

Cork occurs somewhat later than superficial cork and usually in November to December. It is less rare in Australia than superficial cork but is much less frequent than the following forms.

(iii) *Internal cork.*—This has been called confluent bitter pit, pig face, and crinkle, names which are confusing or are in use for other disorders (Section 12).

Internal cork (Figs. 56-58) is the best known of the boron deficiency disorders in apples in Australia and has been found in all States except South and Western Australia. It was first recognized in New South Wales and Tasmania in 1936. It is characterized by lesions in the cortex or core. There are no surface lesions but the fruit may be dwarfed in size, not at all to severely malformed, and may lack juice. It has been found developing in fruit from half to nearly full grown.

The first external evidence, if any, may be a lumpy malformed shape, or dark green watery spots in the skin. The first internal symptom is the presence of small watery greenish rounded areas in the flesh or core usually under 5 mm. in diameter. These areas turn brown from their centres, finally becoming almost black with, in some cases, a greenish border to the cortex lesions, but not to those in the core. These lesions may be confluent and exceed 1 cm. in longest diameter. As the dead tissues dry out they become spongy and may develop cavities.

The earliest lesions may appear in December usually in or near the core. They may, however, develop at any time until the fruit is nearly full grown. The later they develop the nearer they are to the surface. Fruit malformation results mainly from the earlier lesions. The later lesions are smaller and have less effect on the growth of the fruit.

(iv) *Corky core.*—This is the last of the several disorders to develop. The affected fruit (Figs. 57, 58) appears normal in size and appearance. The core area, usually the whole of it, turns brown. Typically the discolouration stops sharply at the core line but this is not invariable. The colour never becomes the dark brown to black of the internal cork lesions. Some authorities (McLarty 1928) include under corky core all lesions occurring within the core line including those in the internal cork of the present classification.

Though not uncommon, corky core is not often noticed by consumers or is regarded as a minor defect. Apples so affected have been marketed and even exported successfully. It resembles core flush (Section 19) but is not evidence of over-storage. Affected apples keep well.

(*b*) *Varietal Susceptibility*

Varietal susceptibility to boron deficiency is marked (Holbeche 1946). Granny Smith and Sturmer are very liable, while Yates, Crofton and Worcester are not known to be affected. There are also varietal differences in susceptibility to the different forms. The more susceptible include:

Cork ..	.. Jonathan, Cox.
Superficial cork	.. Democrat, Jonathan, Cox.
Internal cork	.. Granny Smith, Sturmer, Pomme de Neige, Jonathan, Stone Pippin, Duke of Clarence.
Corky core ..	.. Jonathan, Pomme de Neige, Granny Smith.

(*c*) *Conditions Favouring Cork Disorders*

Boron deficiency in Australia has been found mainly on the granitic tableland belt of New South Wales and Queensland. In Tasmania it has occurred very sporadically, and rarely in many trees in a group. Greatest severity has been noted on sandy or shallow eroded soils which dry out rapidly. Severity has usually been greatest when drought conditions have been experienced in the spring.

(*d*) *Associated Disorders*

Weak growth, dieback of leaders, bark measles, short thickened or flattened lateral and terminal growths, and premature yellowing of foliage may be associated with boron deficiency but any or all of these may be absent. In one instance, the seasonal leader and lateral growths were characterized by a failure of the vascular bundles to fuse into the usual ring of wood. The deficiency may also result in weak growth and poor cropping without definite fruit injury.

(*e*) *Control*

Control by soil dressings of or spraying with borax or boric acid is extremely effective and is so easy that the disorder is now economically unimportant. The best method is to hoe in lightly ¼ to 1 lb. of borax per tree according to size in the autumn or winter. It should be scattered around and between the trees. This will give protection for 3 to 5 years or more. Further treatment should not be given until the disorder is again found. Unnecessary use of borax may cause leaf killing and dieback and affect the quality and storage life of the fruit (Holbeche 1946). Holbeche in a private communication states that, in his experiments, excessive borax definitely reduced fruit size.

(*f*) *Possible Confusion in Diagnosis*

Slight superficial cork may be mistaken for frost russet or spray burn but more severe injury occurs than in those disorders and can usually be found on the trees.

Internal cork has been confused with tree pit. The dark colour of the lesions, the greenish border, if present, and in some cases their presence in the core, and the peculiar fruit malformation distinguish internal cork. It has also been confused with brown heart in stored fruit. The lenticular cavities to which the latter is prone and the absence of malformation help diagnosis. It has been confused with crinkle, in which, however, the larger and lighter coloured lesions always near the skin, the frequent discolouration of the latter, and the different type of malformation are distinctive.

Corky core might be confused with core flush and cannot always be separated. It is more frequently confined to within the core line. It is, however, best separated by the condition of the fruit which should not show core flush until late in the storage life.

Section 33. Disorders Caused by Cool Storage and Post-storage Conditions

This section deals with disorders which may originate in or after cool storage. It does not include those which may have originated earlier and are first noted in cool-stored fruit.

(*a*) *Core Flush* (Section 19).—Caused by over-storage especially of more or less immature fruit. Stimulated by high temperatures and carbon dioxide in the storage atmosphere approaching the critical amount for brown heart. Not confined to cool storage.

(*b*) *Over-maturity Breakdown* (Section 19).—Caused by storage of apples until they have passed eating ripeness. Storage life is shortest in light crops and large sized fruit. Rapid growth prior to picking, delayed storage, and high storage temperatures hasten onset. Storage life varies greatly with variety.

(*c*) *Watercore Breakdown* (Section 19).—Apples with severe early watercore in cool storage and especially apples with late watercore at any temperature are liable to breakdown.

(*d*) *Pit Breakdown* (Section 19).—Apples mature enough to ripen in storage tend to develop senescent breakdown prematurely if affected with pit. Not confined to cool storage.

(*e*) *Bruise Breakdown* (Section 19).—Apples if bruised when ripe tend to breakdown prematurely. This does not apply to bruising sustained before ripening. Not confined to cool storage.

(*f*) *Low Temperature Breakdown* (Section 19).—Certain varieties grown in the cooler areas, notably in Tasmania and Victoria, are subject to low temperature breakdown if held long enough below a critical temperature, usually 36°-38°F. Liability is greatest in light crop and large fruit and increases with the length of storage.

(*g*) *Deep Scald* (Section 19).—A form of low temperature breakdown confined to the outer cortex of certain varieties, notably Jonathan. Liability is greatest in light crop and large fruit when held below a critical temperature of 36°-38°F., as it approaches eating ripeness. Liability then declines and further development of the disorder ceases.

(*h*) *Brown Heart* (*CO_2 Injury*) *and Oxygen Deficiency Breakdowns* (Section 19).—Disorders caused by an accumulation of excessive CO_2 (about 10 per cent. or more) or a deficiency of oxygen in the storage atmosphere. Liability increases with increasing temperature and increasing maturity of the fruit. Up to a critical point increased CO_2 and reduced oxygen is useful in delaying maturity. This is made use of in gas storage.

(*i*) *Early Superficial Scald* (Section 18).—Caused by the accumulation of gaseous emanations from the fruit but not by CO_2. It is increased by lack of ventilation and fruit must be protected in gas storage by wrapping in oiled paper.

(*j*) *Late Scald* (Section 18).—A senility disorder often preceding or accompanying low temperature breakdown.

(*k*) *Jonathan Spot* (Section 17).—A disorder of certain red varieties approaching the end of their storage life. Not confined to cool storage. Controlled by oil or wax treatments or gas storage.

(*l*) *Lenticel Storage Spot* (Section 17).—A senile disorder of the lenticels not confined to cool storage. Often precedes spot rotting of stored fruit. Can be induced by skin treatments (Section 31) and ammonia fumes (Section 18).

(*m*) *Rots following Non-parasitic Disorders* (Section 21).

(*n*) *Freezing Breakdown* (Section 19).—Follows exposure of fruit to temperatures below about 29°F. Injury is increased by length of exposure.

(*o*) *Storage Pit* (Section 15).—A spotted flesh disorder of many varieties when picked while still rich in starch but mature enough to ripen. Susceptibility is greatest in light crop and large fruit. Not confined to cool-stored fruit. The rate of onset is increased by the temperature of storage but the percentage of fruit materially affected is usually less in ordinary than in cool storage temperatures. Varietal liability varies greatly.

(*p*) *Bruises* (Section 9).—Ripe fruit in and after storage is very subject to bruising through rough handling.

(*q*) *Light-induced Scald* (Section 18).—Yellow varieties which have become ripe or nearly so in cool storage are subject to a brown scald when exposed to direct sunlight, as in shop windows. Tree-ripened fruit is also susceptible.

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PLATE 1

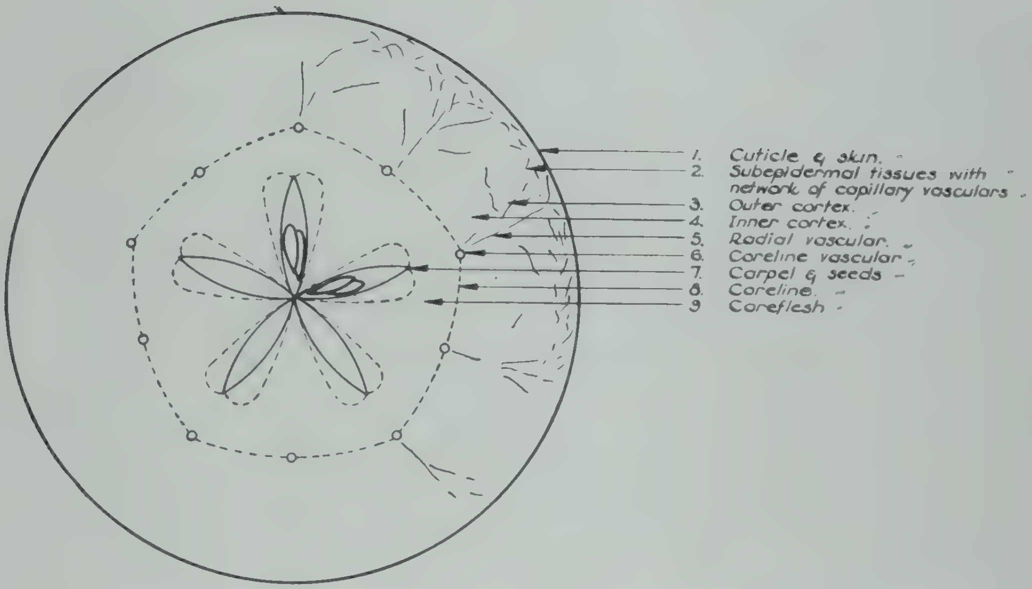


FIG. 1.—Diagrammatic median cross section of an apple.

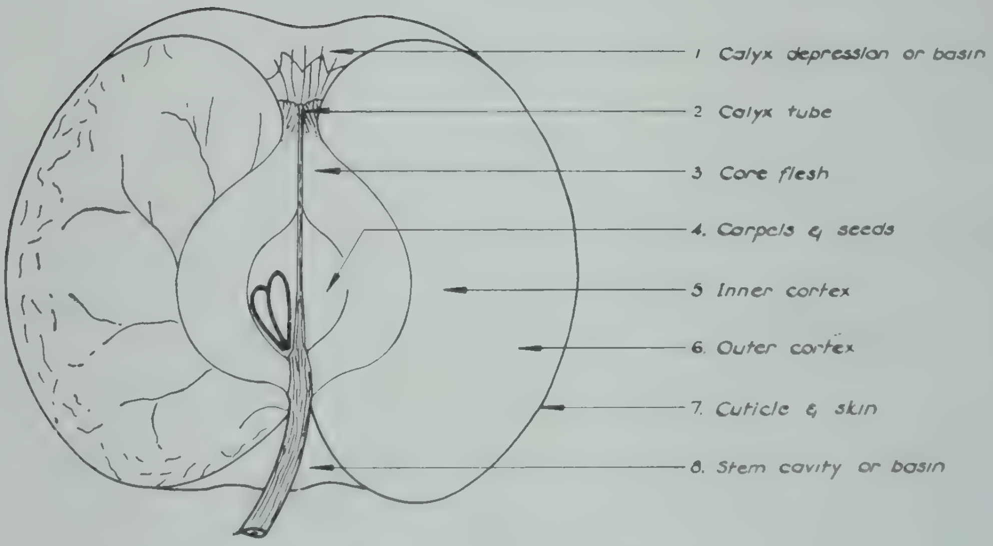


FIG. 2.—Diagrammatic median longitudinal section of an apple.

PLATE 2

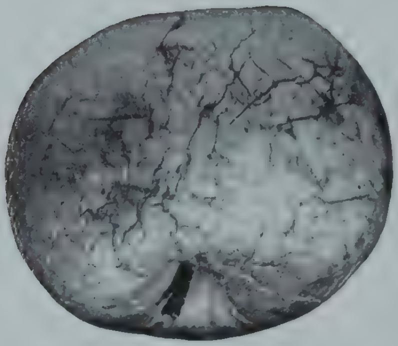


FIG. 3.—Wilt. Jonathan.

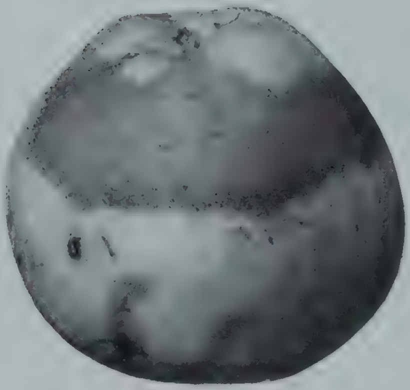


FIG. 4.—Frost band. Sturmer.

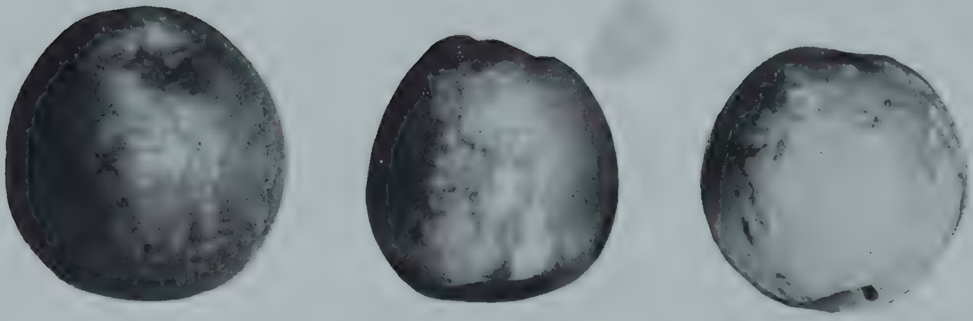
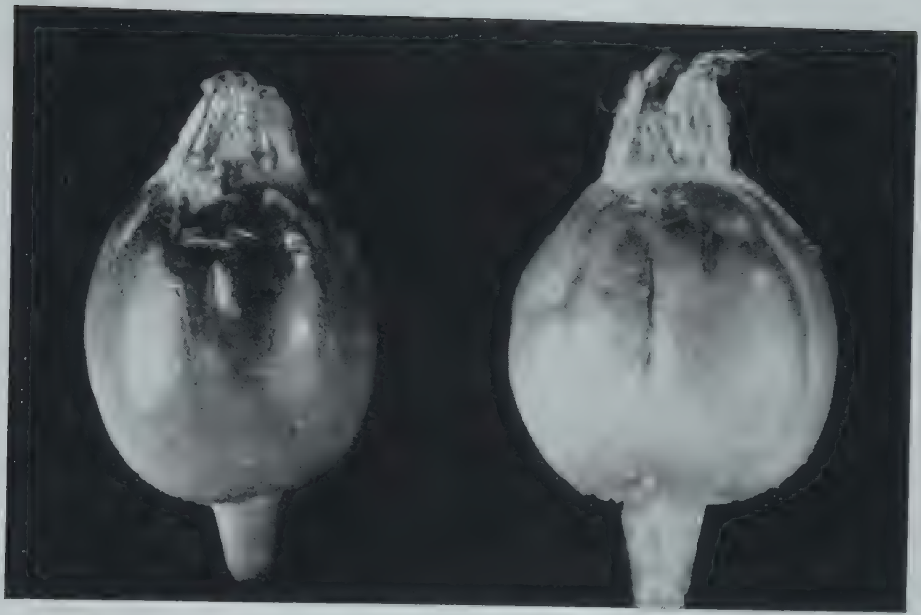
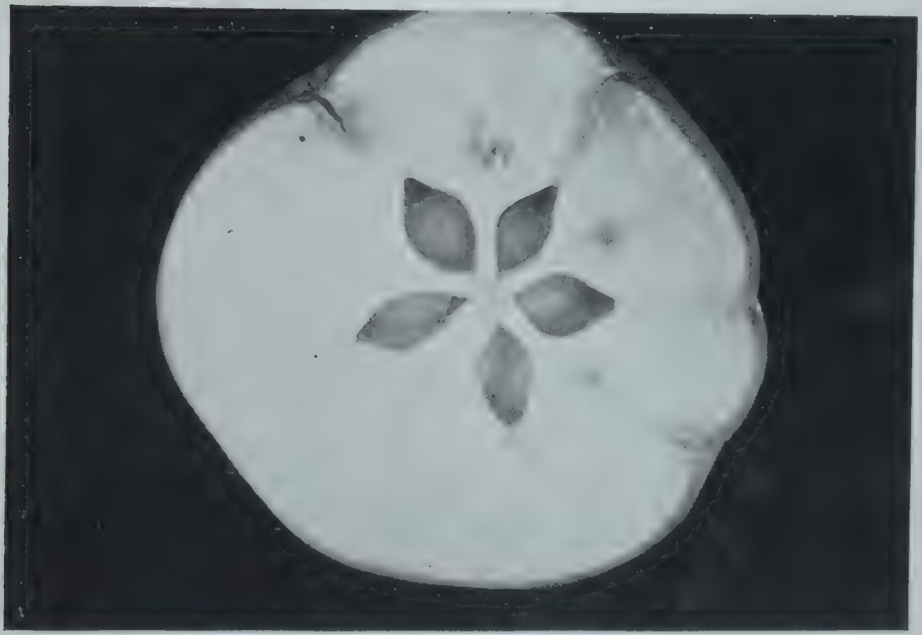


FIG. 5.—Bordeaux spray russet. Left to right: Granny Smith, Cleopatra, Sturmer.



[*Photo: D. Martin.*

FIG. 6.—Frost crack in recently set Cleopatra.



[*Photo: D. Martin.*

FIG. 7.—Frost crack. Cross section of an apple in Fig. 6.

PLATE 4

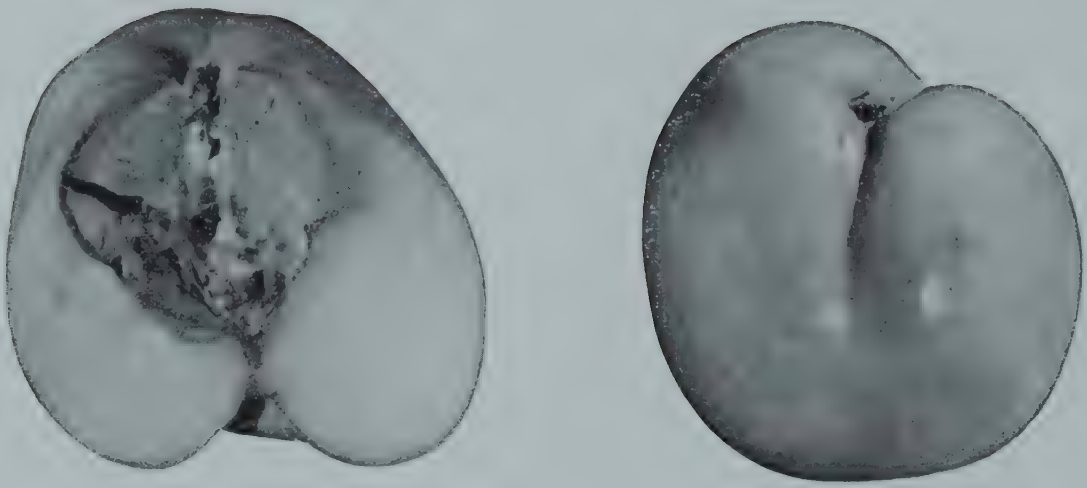


FIG. 8.—Split core with mouldy core starting. Cleopatra.

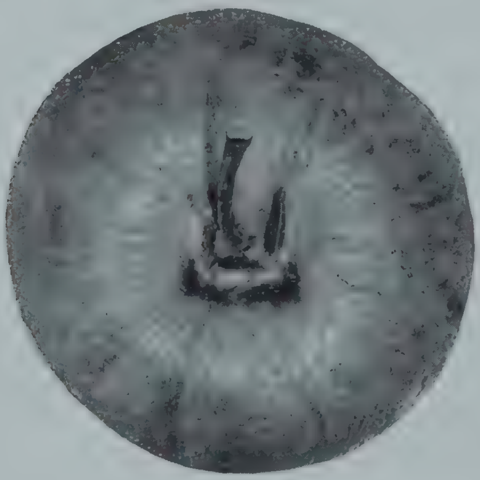
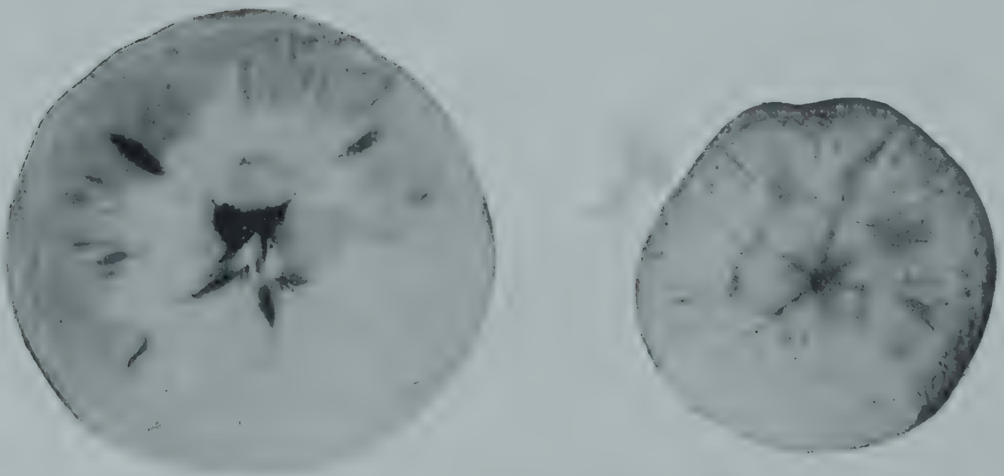


FIG. 9.—Stem-end blister. Yates.



[*Left photo: Dom. Canada Dep. Agric.*
FIG. 10.—Radial watercore and breakdown. Jonathan.

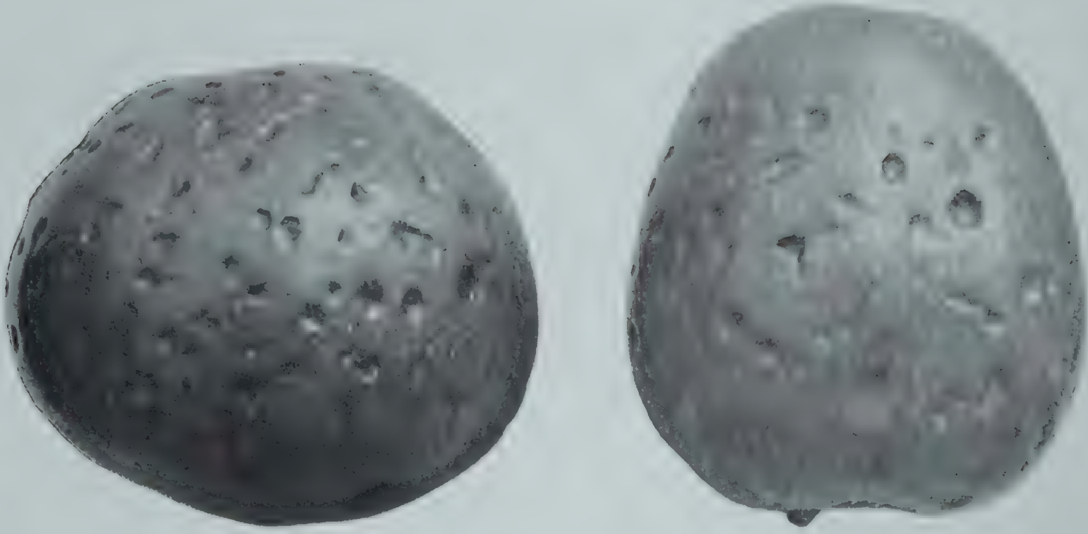


FIG. 11.—Severe cool storage pit. Dunns (left) and Cleopatra.

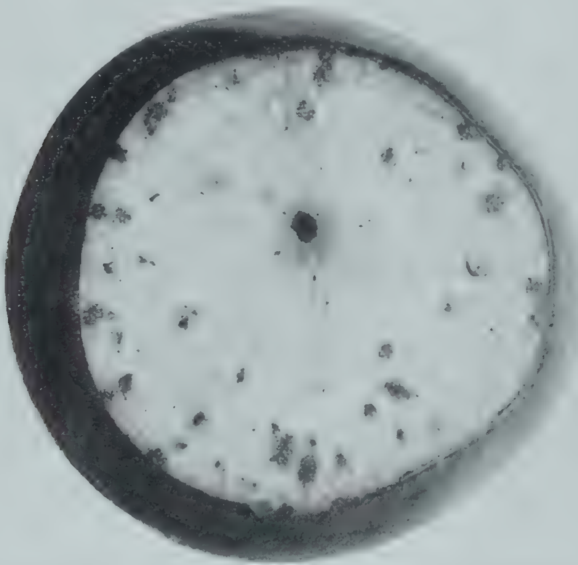


FIG. 12.—Internal lesions of normal storage pit. Cleopatra.

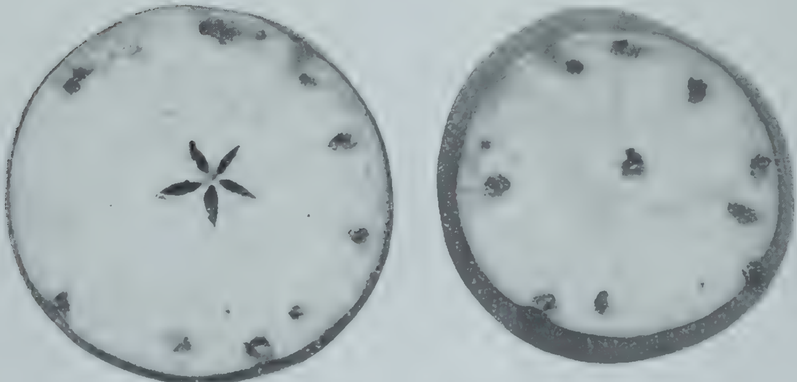


FIG. 13.—Internal lesions of severe cool storage pit. Cleopatra.

PLATE 6

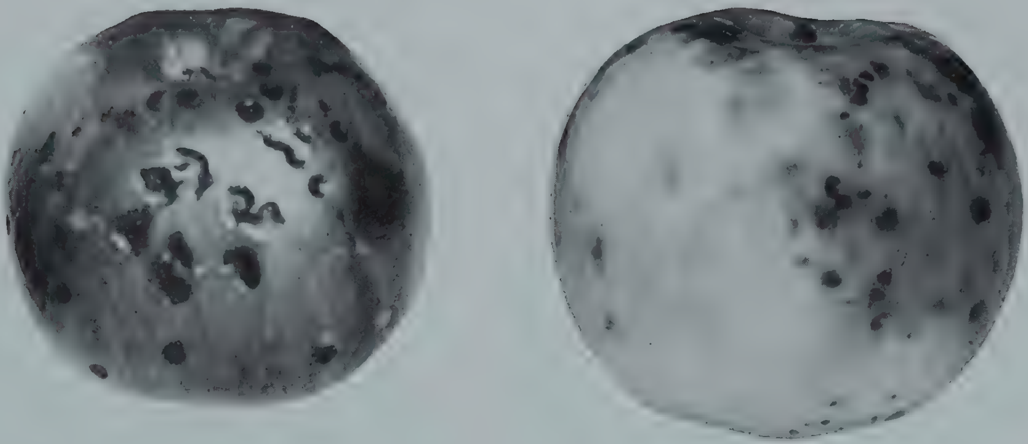


Fig. 14.—Lenticel blotch pit (left) and normal storage and lenticel blotch pit (right). Jonathan.

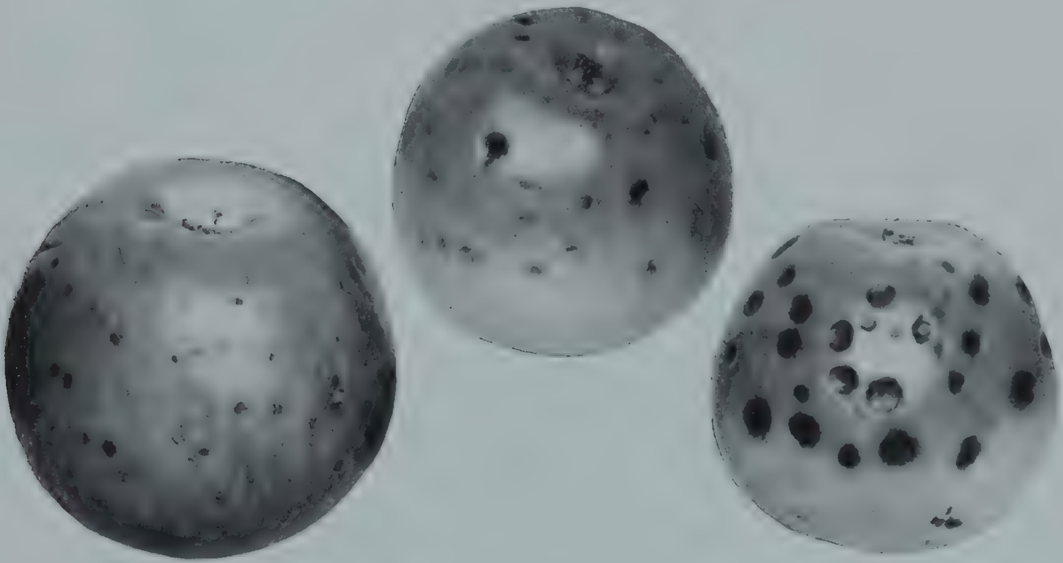


Fig. 15.—Storage pit. Normal, Jonathan (left); normal and severe cool storage pit, Granny Smith (centre); severe cool storage pit, Granny Smith (right).

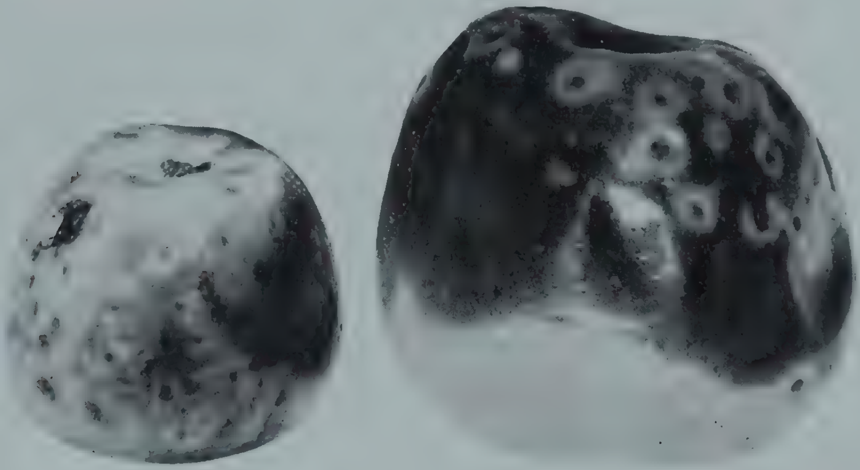


Fig. 16.—Pit breakdown. Cox (left) and Cleopatra (right). Note zone around pits not discoloured.

PLATE 7

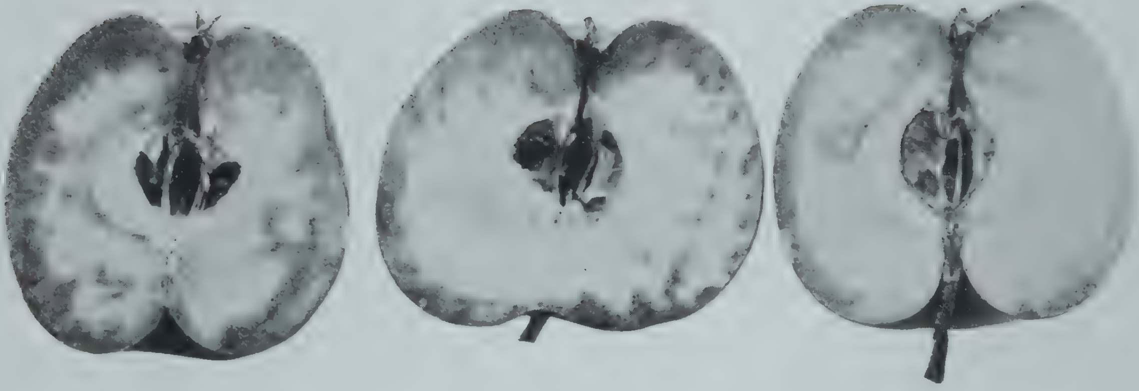


Fig. 17.—Iodine-starch reaction. Longitudinal sections through Cleopatra. Note starch loss proceeding from stem to calyx ends and from core to surface.

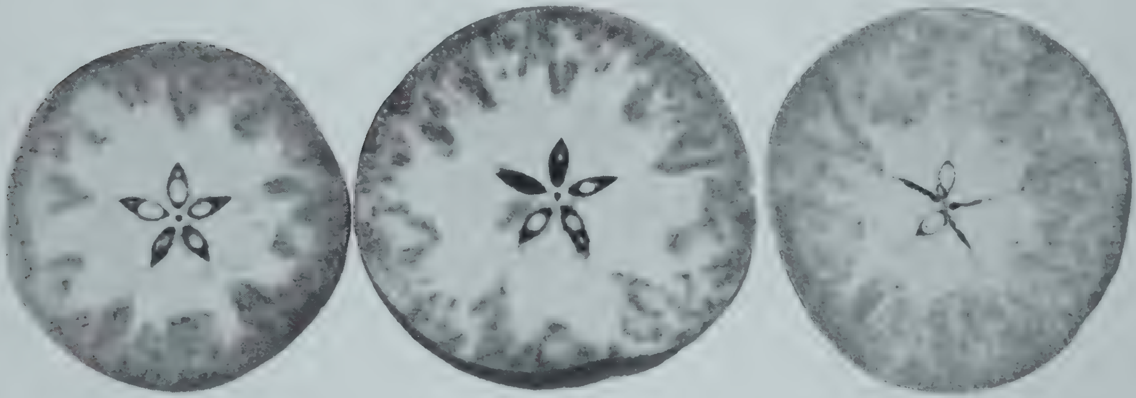


Fig. 18.—Iodine-starch reaction. Cross sections through Granny Smith, showing starch pattern associated with vasculars.

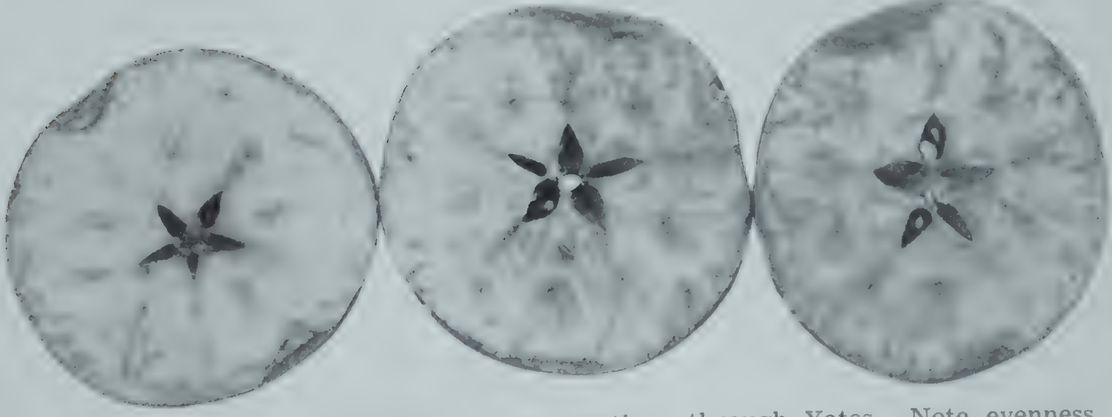


Fig. 19.—Iodine-starch reaction. Cross sections through Yates. Note evenness of starch loss and its persistence in bruises.

PLATE 8

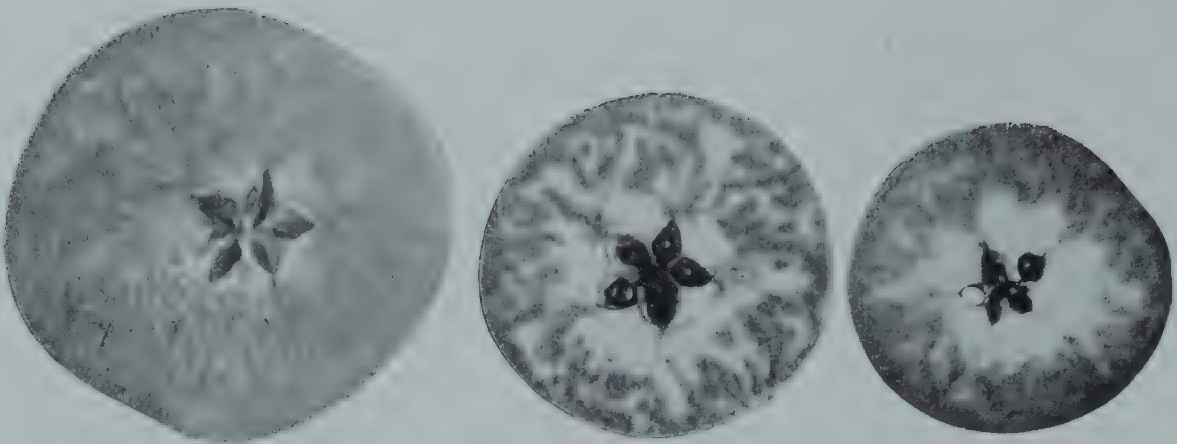


Fig. 20. Iodine-starch reaction of freshly picked apples. Cross sections through Cleopatra showing progressive starch loss. The apples range from too immature to ripen or pit (left), to pit-liable (centre).

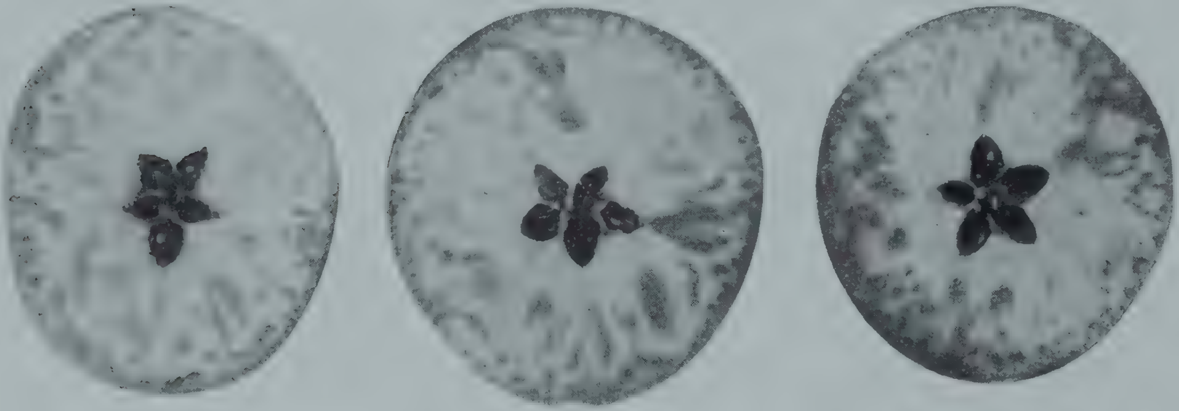


Fig. 21.—Iodine-starch reaction of freshly picked apples. Cross sections through Cleopatra showing a maturity too advanced for pitting.

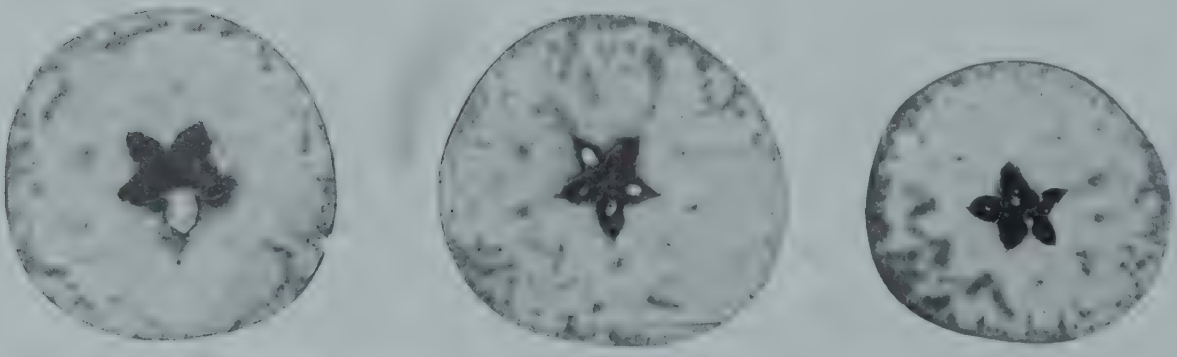


Fig. 22. Iodine-starch reaction of freshly picked apples. Cross sections through Cleopatra showing a maturity too forward for long storage or export.

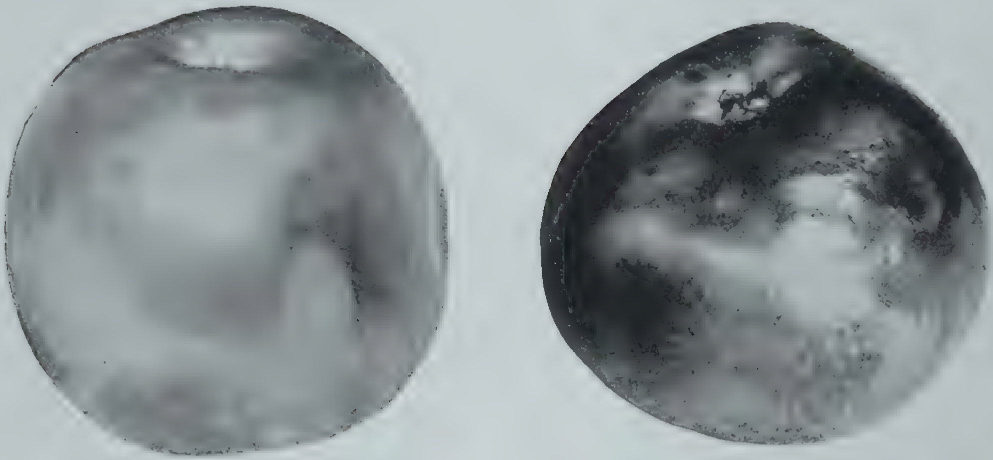


FIG. 23.—Early watercore visible through skin. Ribston (left) developing breakdown; French Crab (right) developing crinkle.

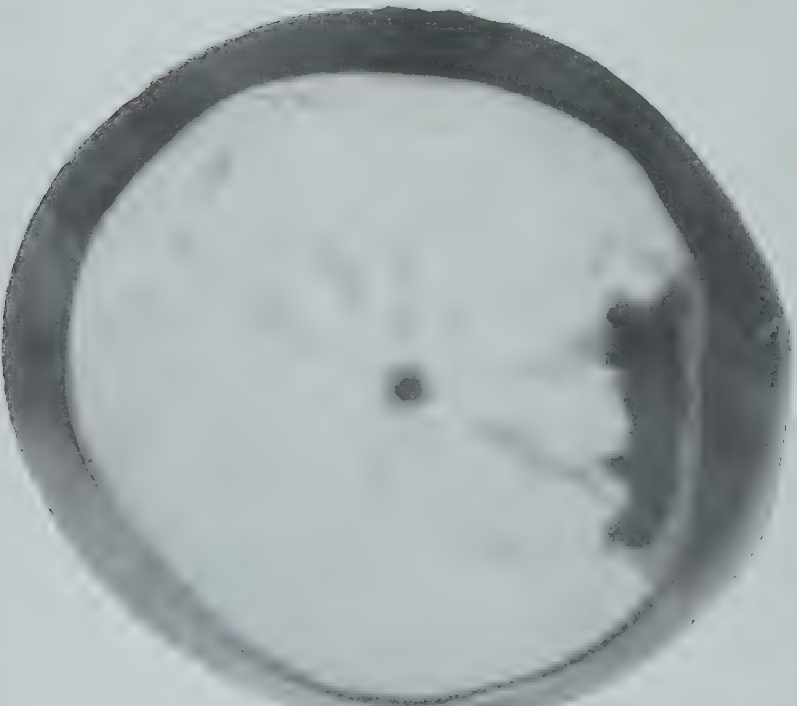


FIG. 24.—Early watercore. Cross section through Democrat showing crinkle developing with death of watercored tissues.

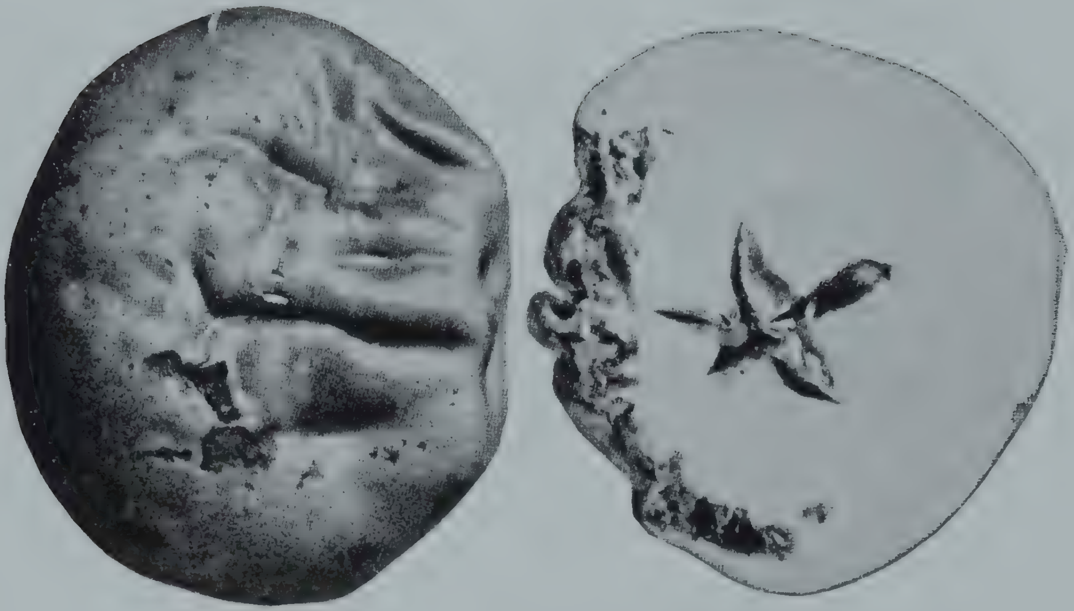


FIG. 25.—Severe crinkle. London Pippin (after McAlpine).

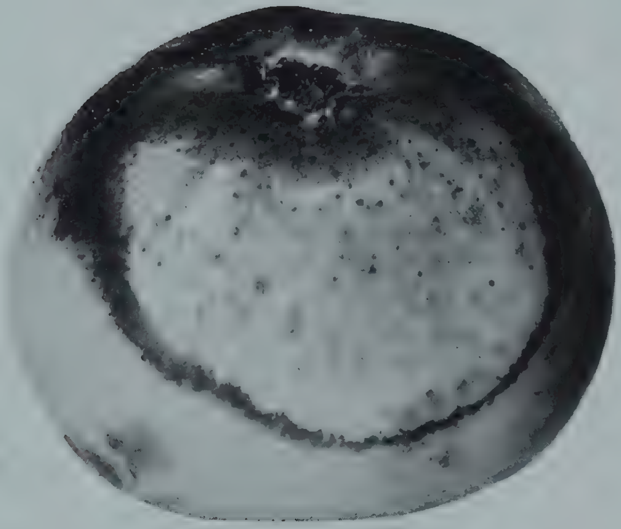


FIG. 26.—Watercore sunburn. London Pippin.

PLATE 11

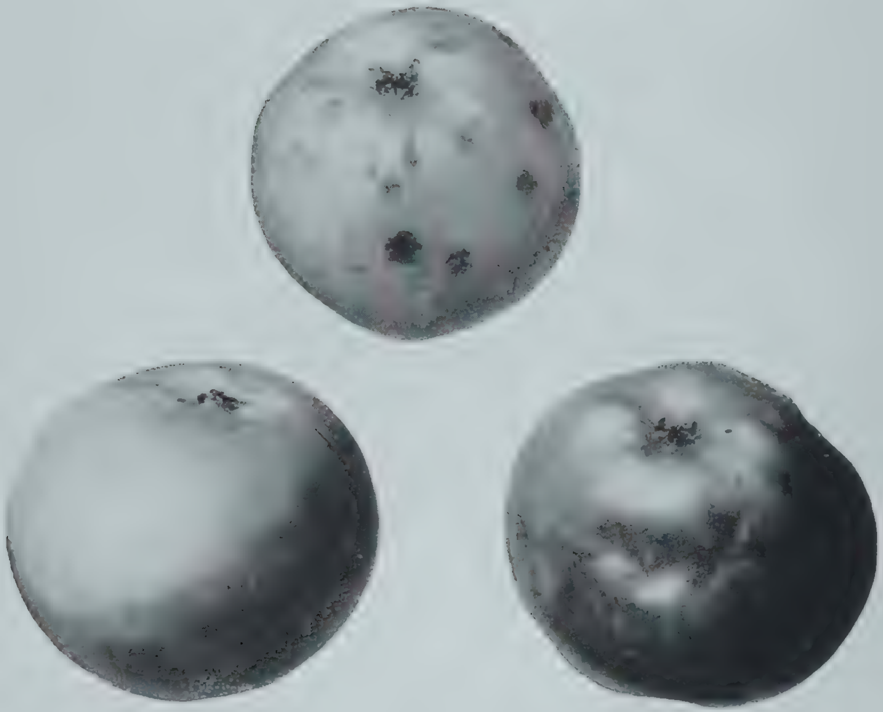


FIG. 27.—Crinkle pit in French Crab; slight (left), severe (centre), crinkle (right).

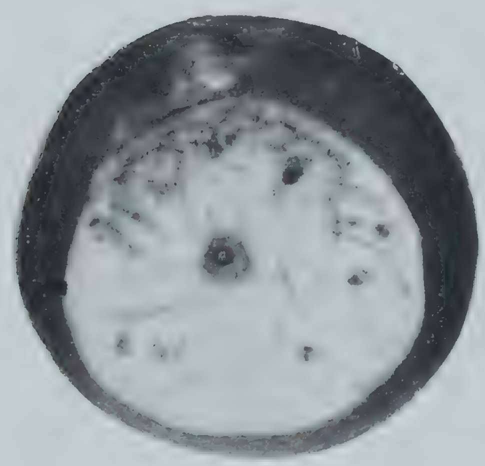


FIG. 28.—Crinkle and crinkle pit lesions in same apple. French Crab.

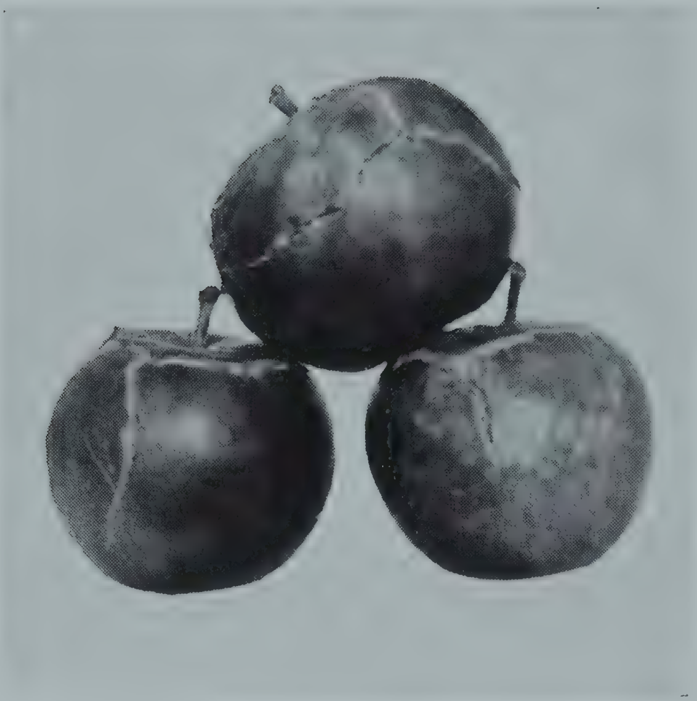


FIG. 29.—Breakdown crack. Jonathan.

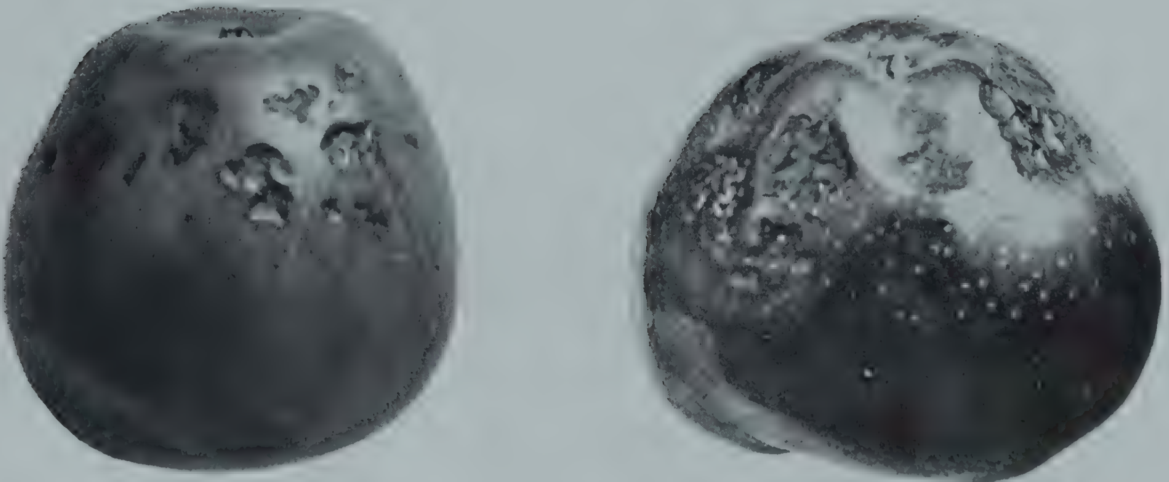


FIG. 30.—Blotchy tree pit. Cleopatra.

PLATE 13

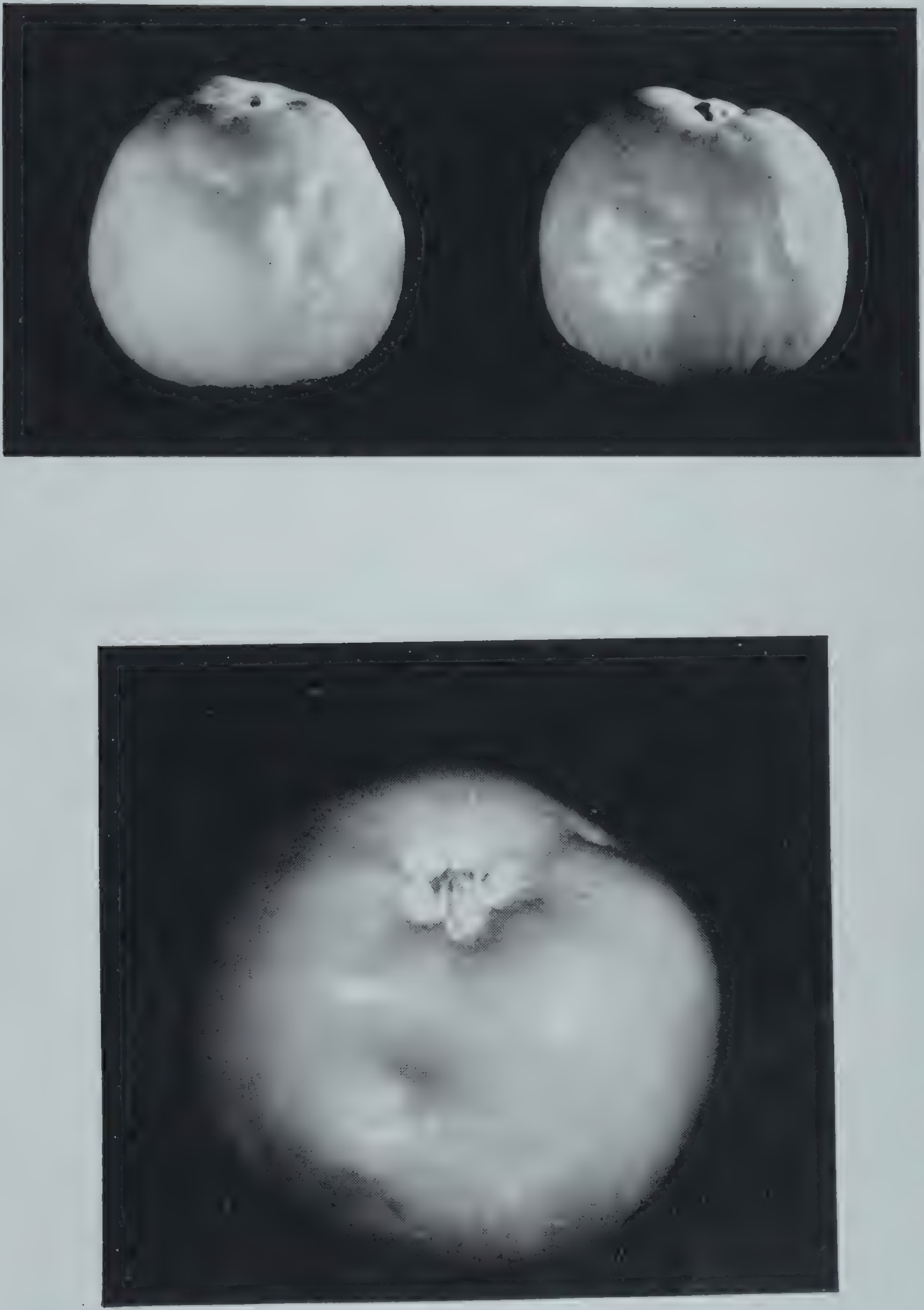


FIG. 31.—Dimple in Granny Smith; persistent (above) and sporadic (below) types.

PLATE 14

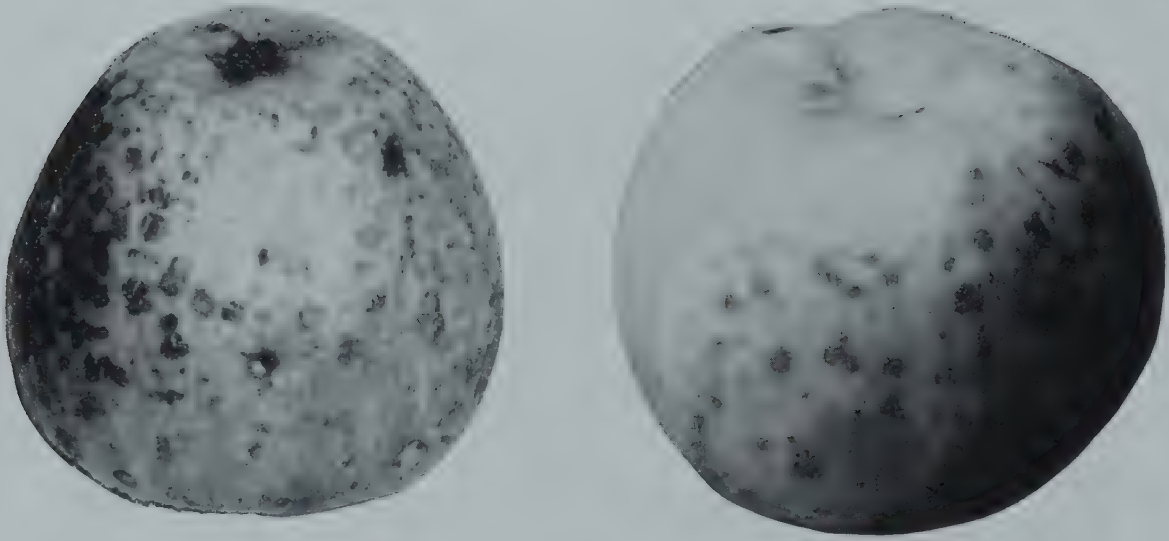
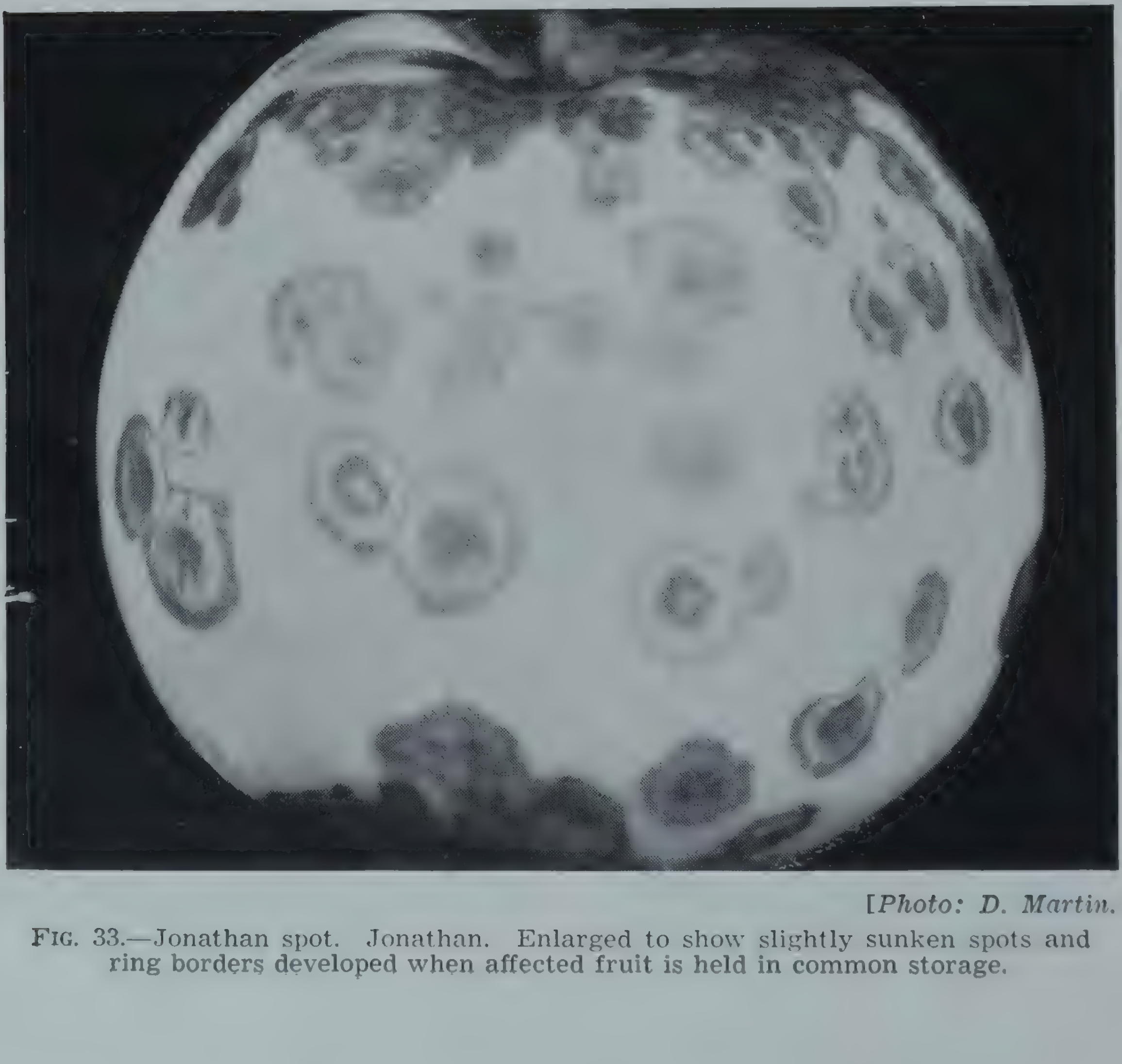


FIG. 32.—Jonathan spot. Worcester (left) and Jonathan.



[*Photo: D. Martin.*

FIG. 33.—Jonathan spot. Jonathan. Enlarged to show slightly sunken spots and ring borders developed when affected fruit is held in common storage.

PLATE 15

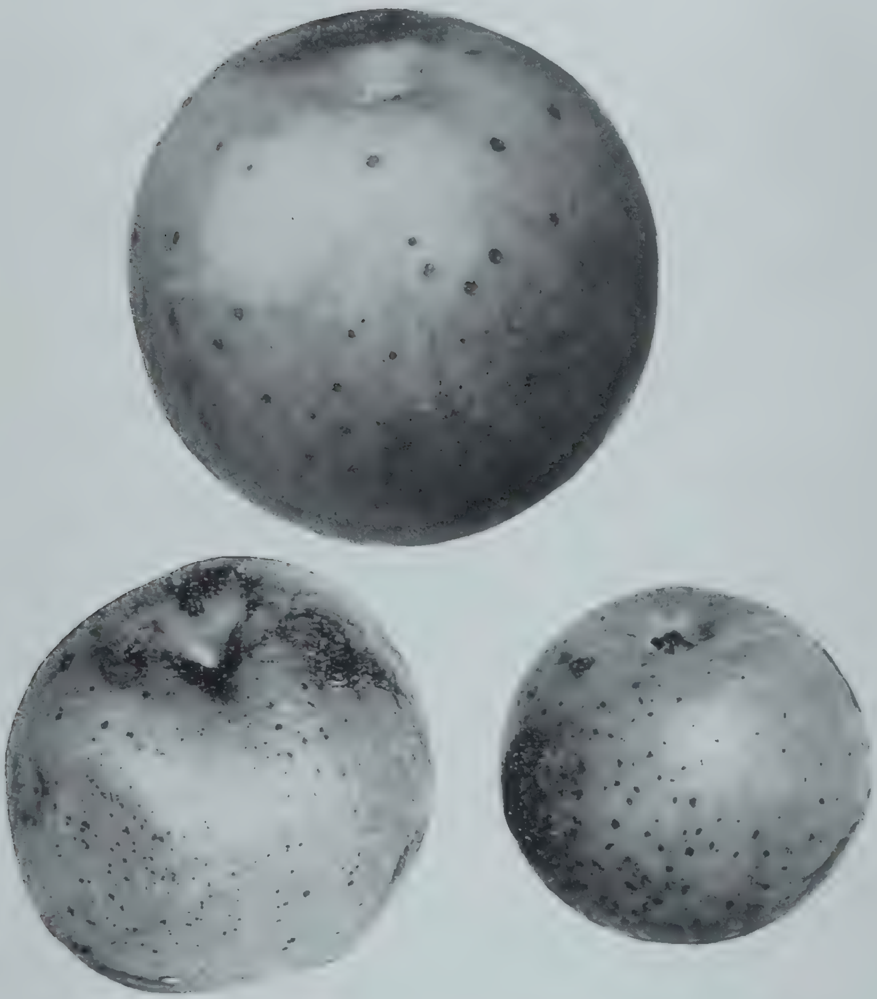


FIG. 34.—Lenticel storage spot. Jonathan (above), Cleopatra (left), and Rome Beauty (right).

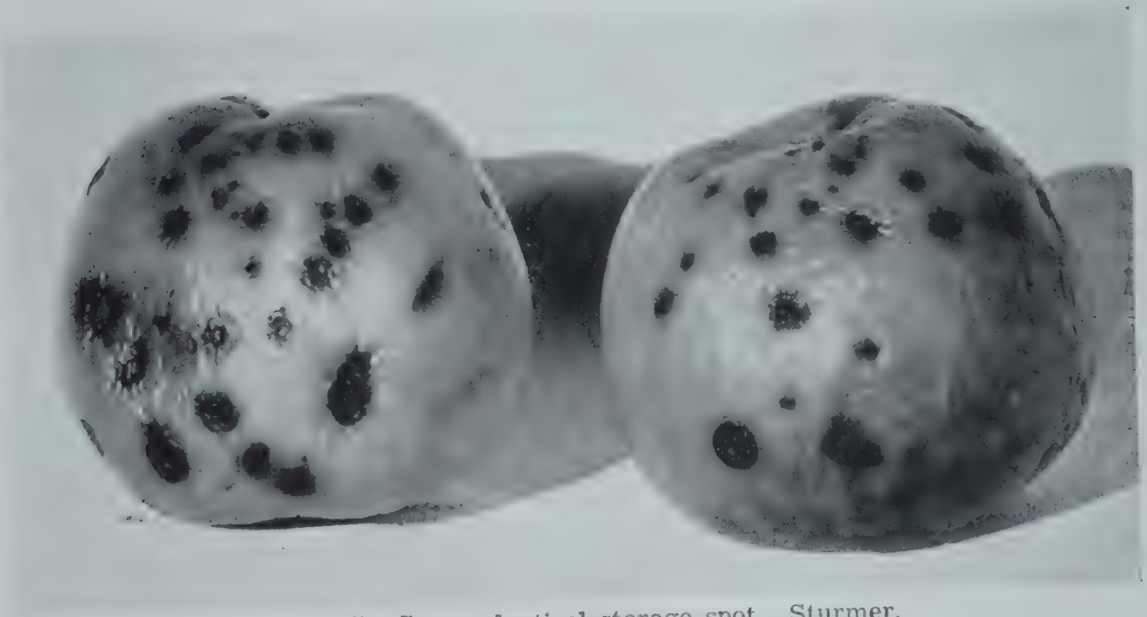


FIG. 35.—Severe lenticel storage spot. Sturmer.

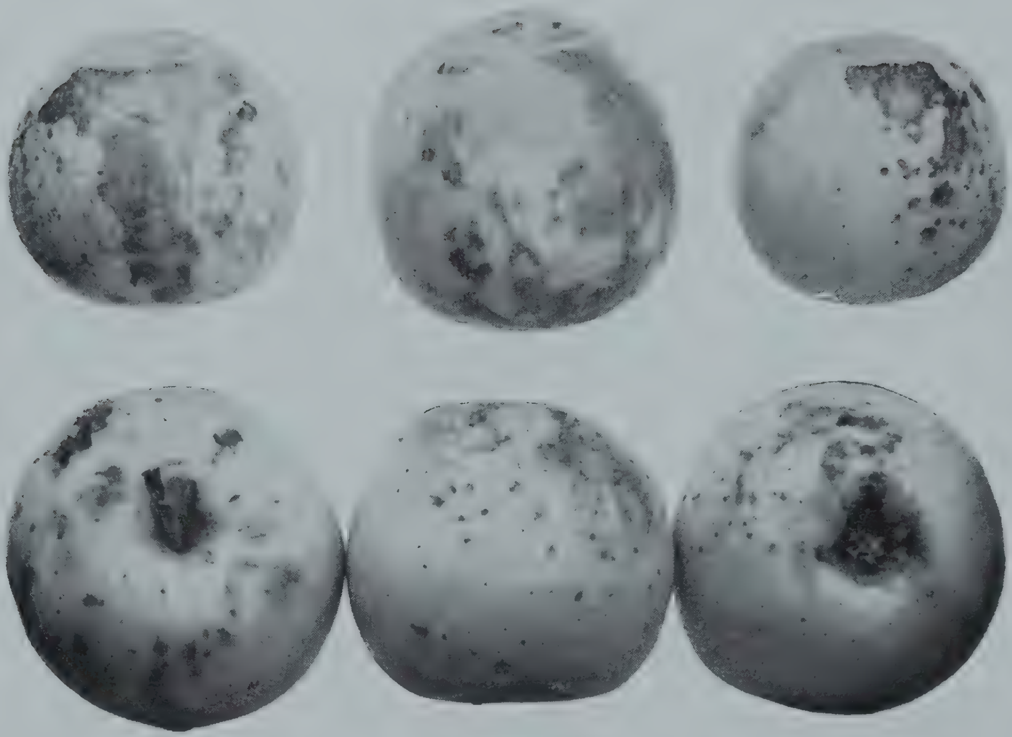


FIG. 36.—Superficial and lenticel scald. Granny Smith.

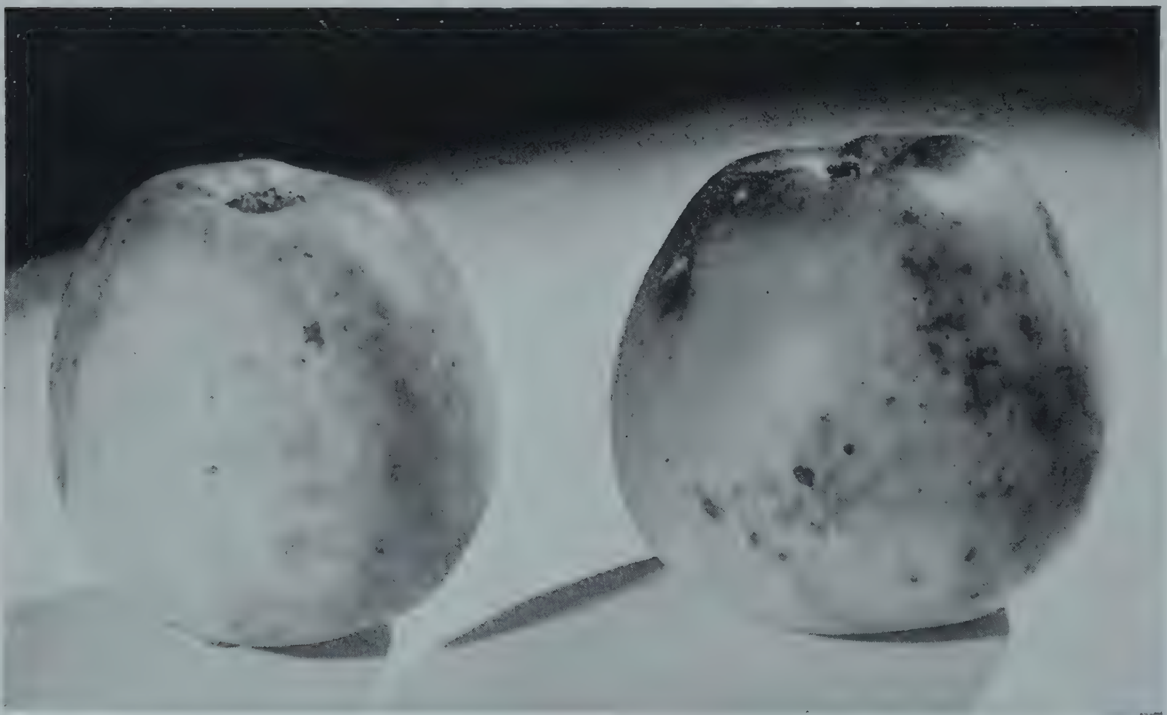


FIG. 37.—Orchard or light-induced scald. Sturmer.

PLATE 17

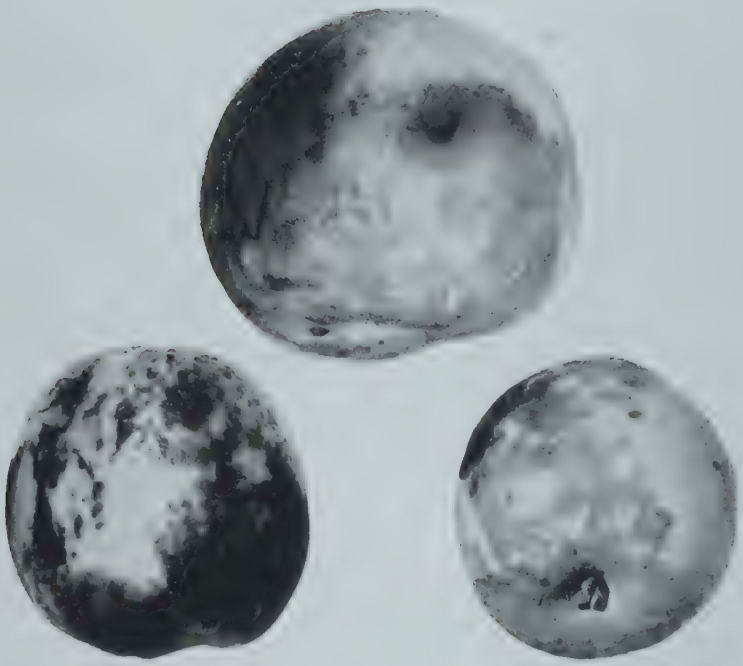


Fig. 38.—Late scald. Crow Egg (top), Cleopatra (left), and Ribston (right).

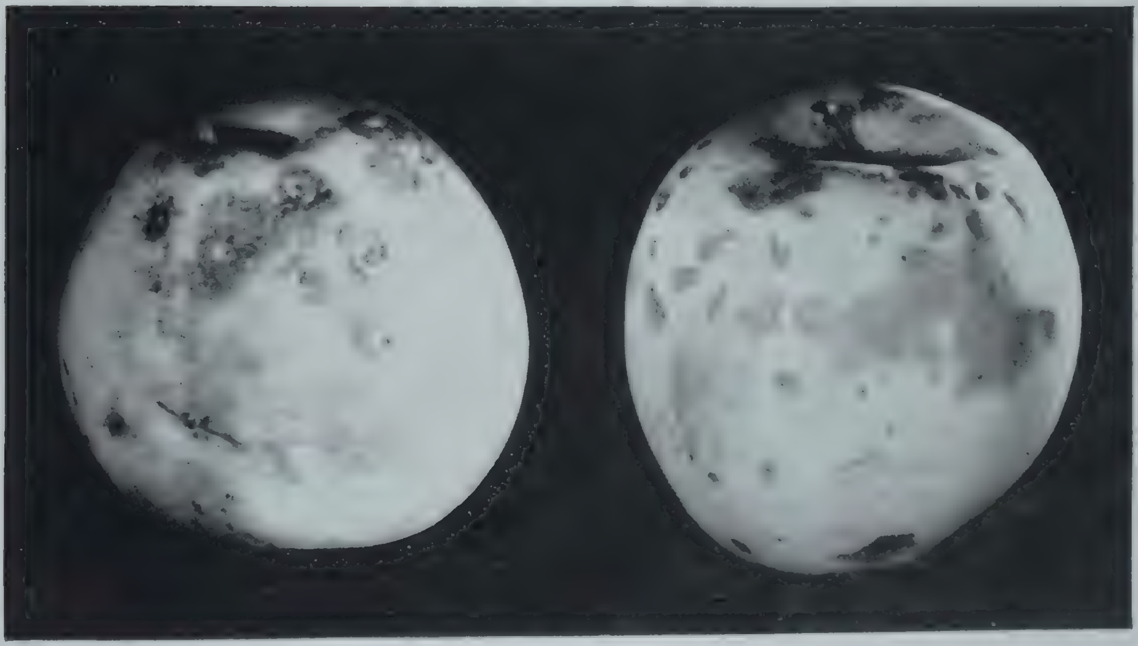


Fig. 39 (left).—Late scald associated with storage pit. Cleopatra.

Fig. 40 (right).—Severe light-induced scald. Cleopatra.

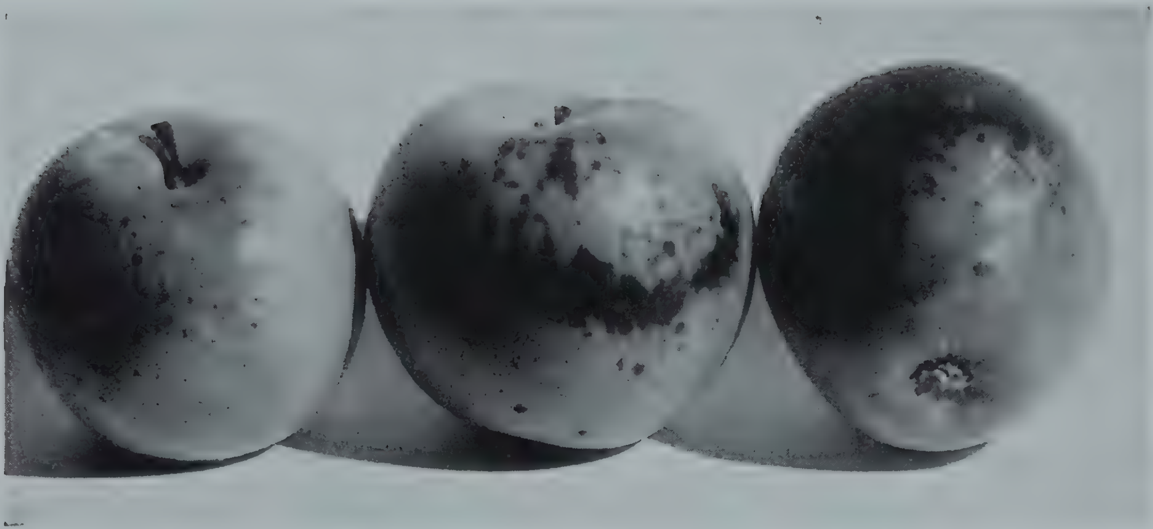


FIG. 41.—Sunburn scald. Granny Smith.

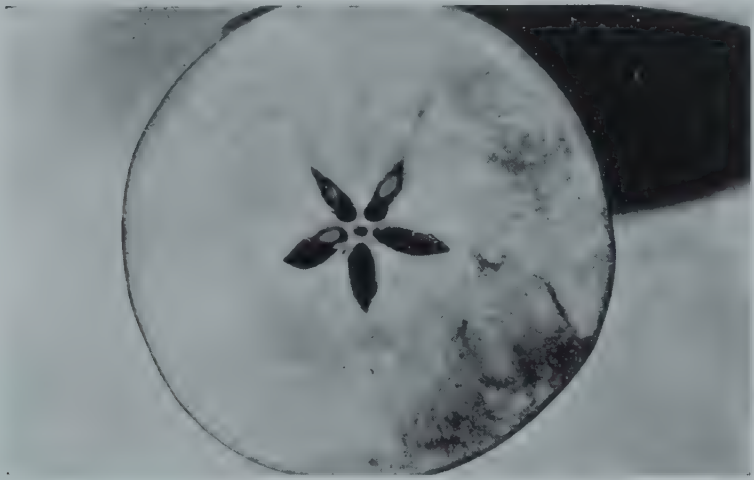


FIG. 42.—Over-maturity senescent breakdown. Granny Smith.

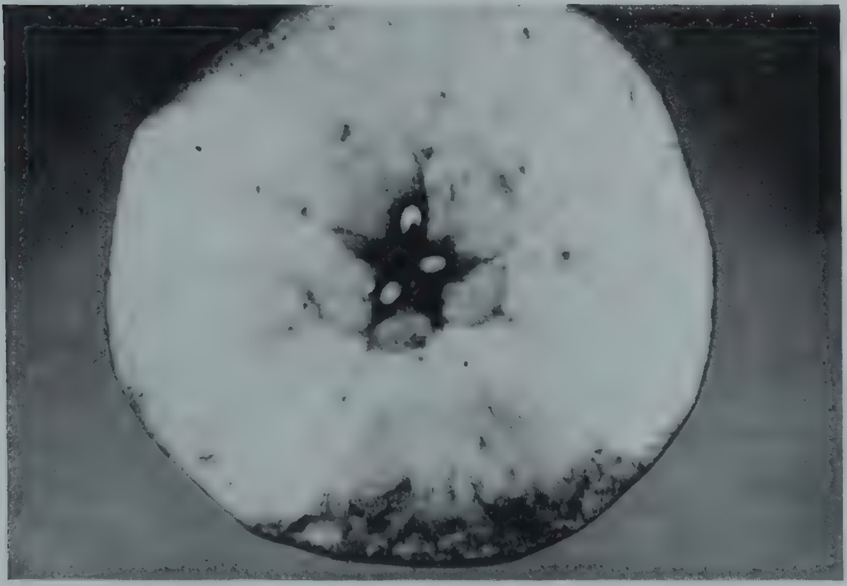


FIG. 43.—Bruise breakdown. Jonathan.

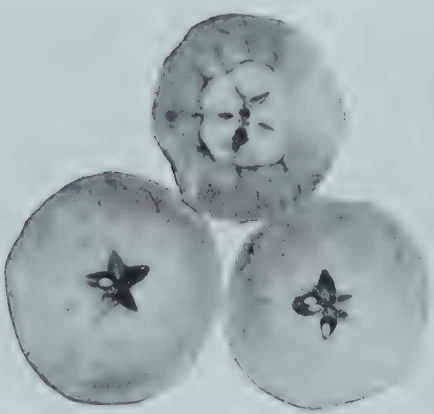


FIG. 44.—Low temperature breakdown. Jonathan.

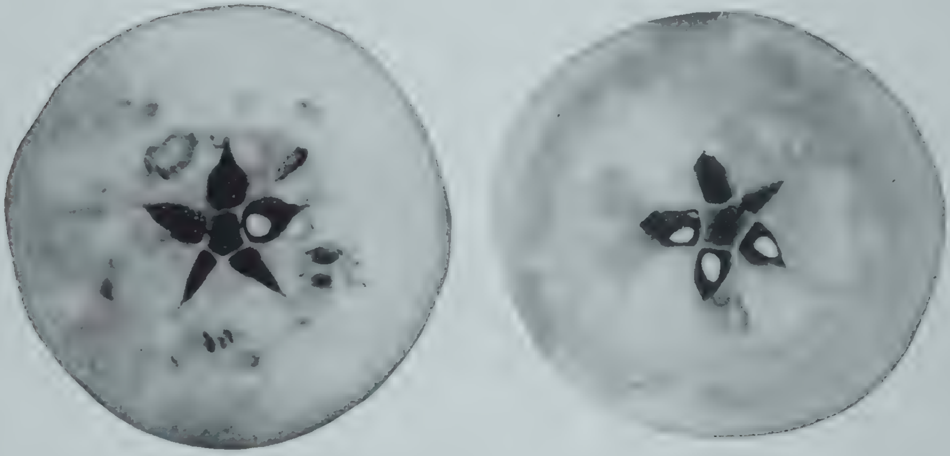
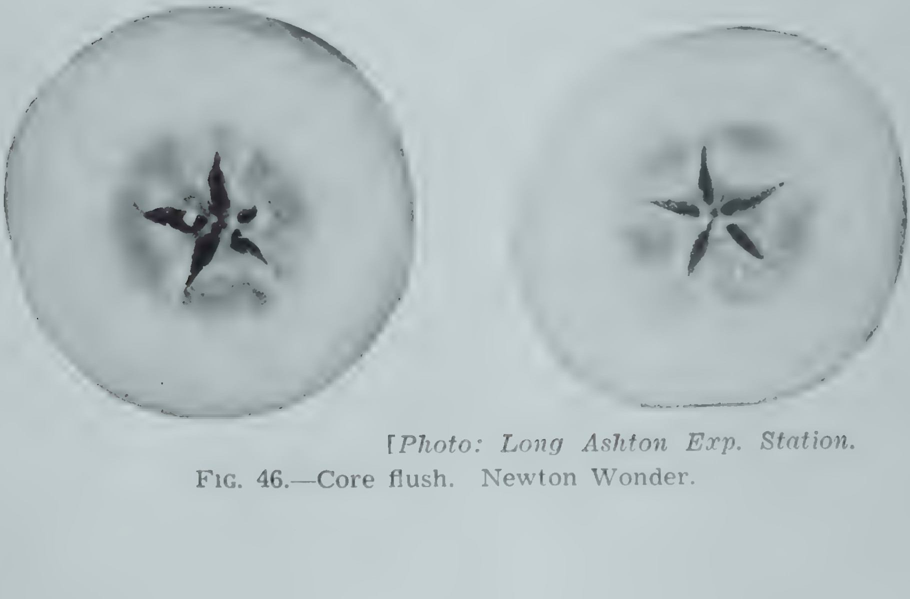


FIG. 45.—Low temperature breakdown with brown heart. French Crab.



[Photo: Long Ashton Exp. Station.

FIG. 46.—Core flush. Newton Wonder.

PLATE 20

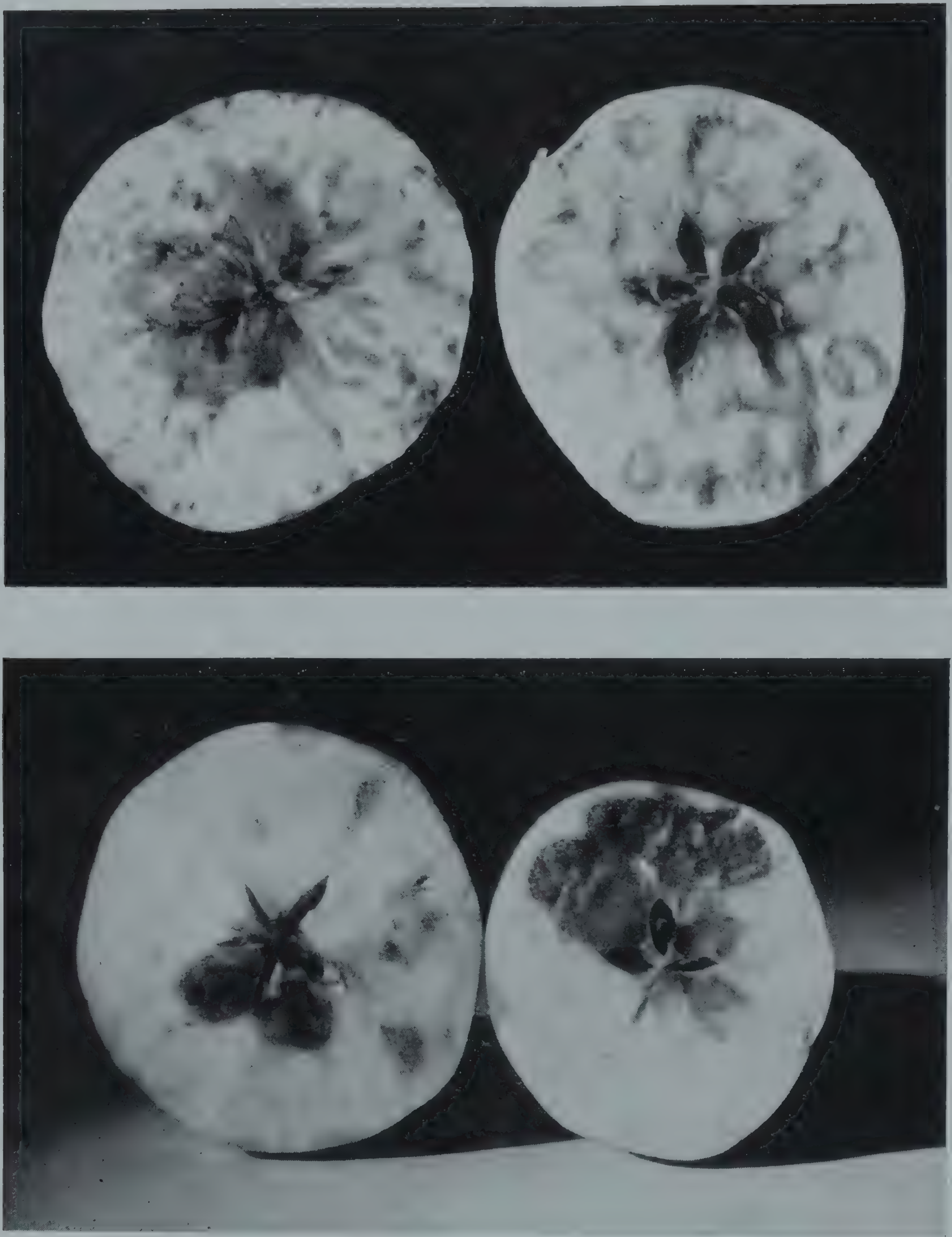


FIG. 47.—Brown heart. Sturmer. Developed in fruit enclosed 6 days in air-tight container (above); the CO_2 content of the air rose to 23 per cent. Developed in 2 weeks in air containing 12 per cent. CO_2 (below). Photos taken before lesions dried out.

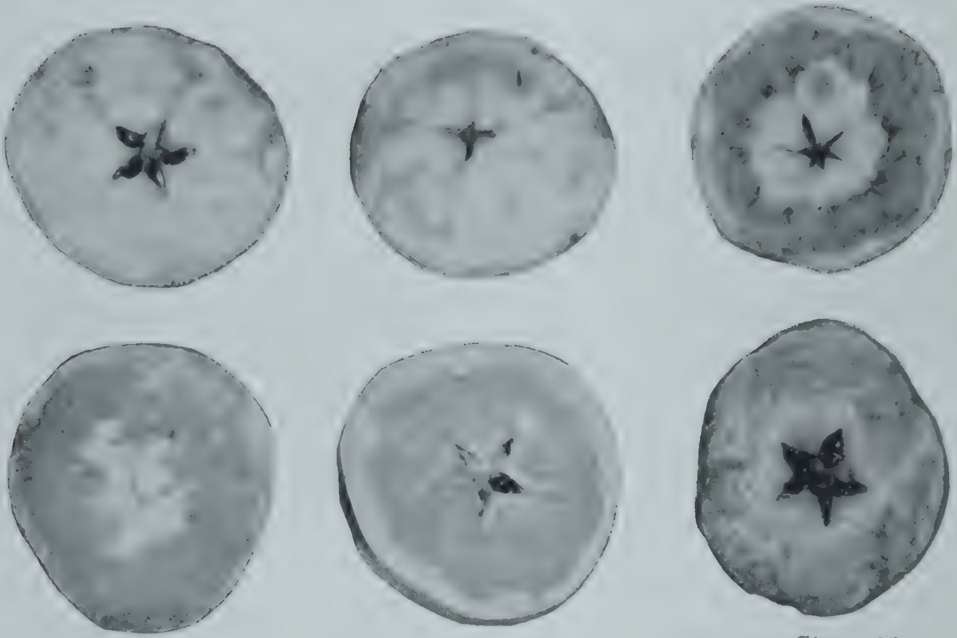


FIG. 48.—Brown heart. Upper row Scarlet; lower row Sturmer.

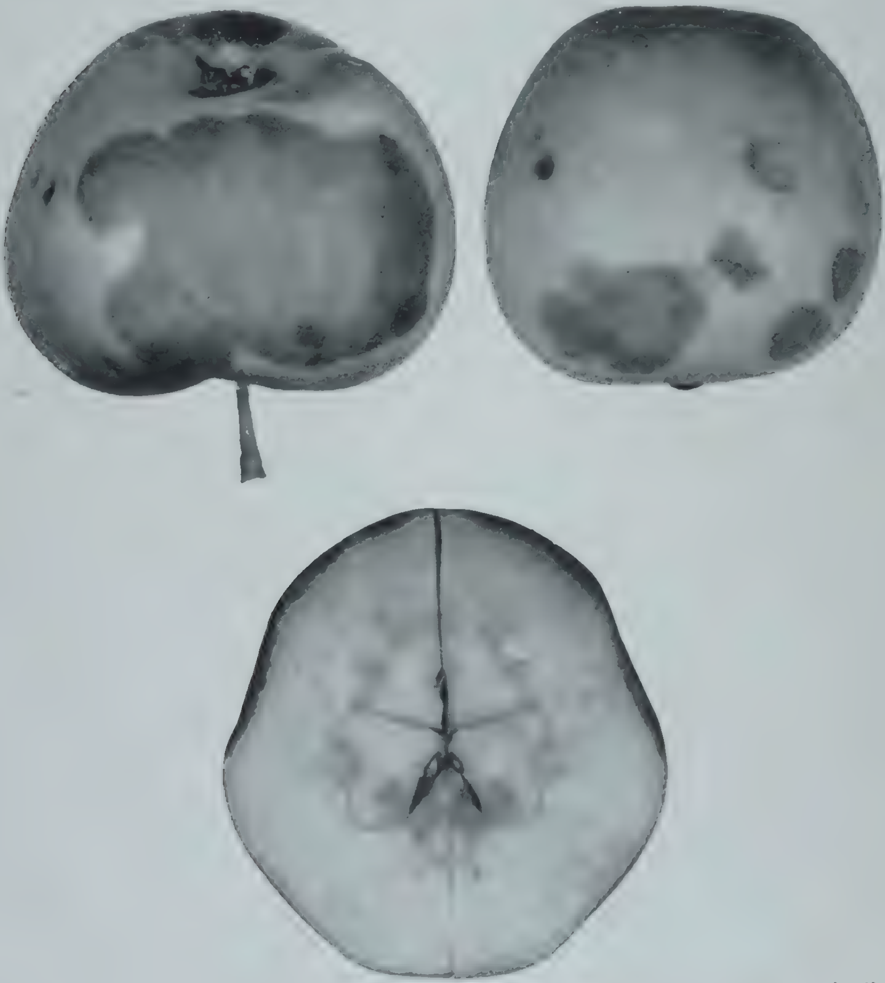


FIG. 49.—Alcoholic breakdown. Sturmer. The cross section shows also brown heart in core.

PLATE 22

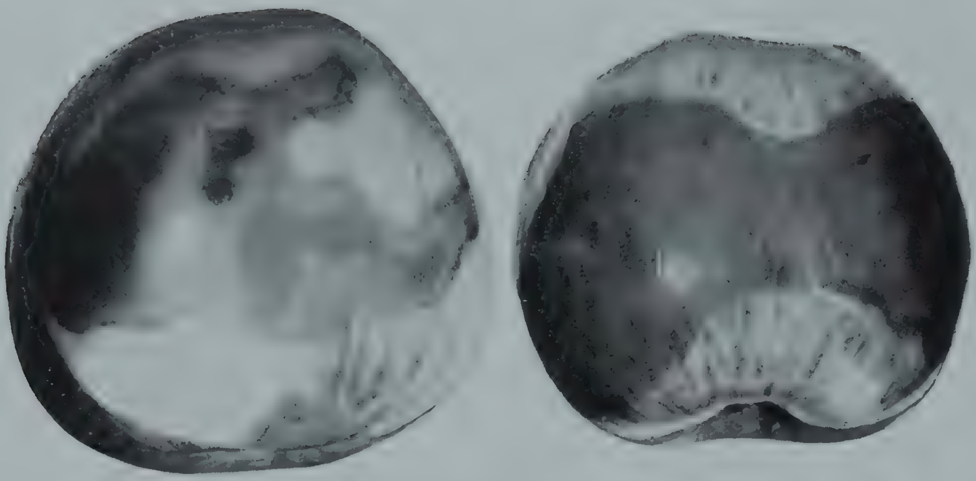


FIG. 50.—Deep scald. Jonathan.

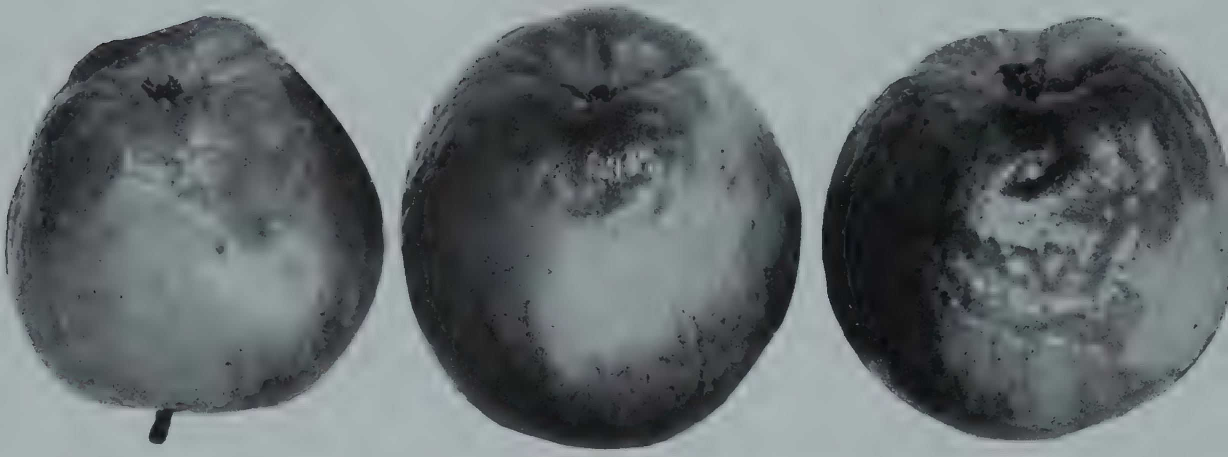


FIG. 51.—Freezing scald. Worcester. Unusual form resembling crinkle and alcoholic breakdown.

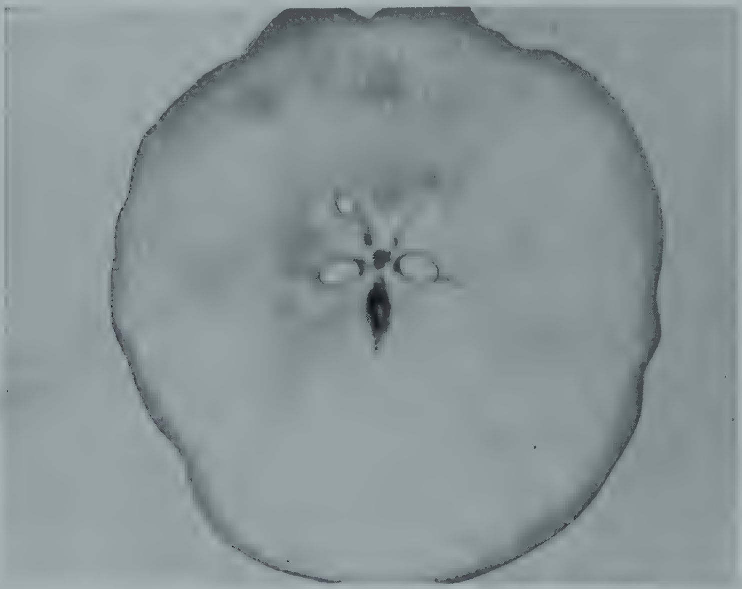


FIG. 52.—Freezing breakdown. Granny Smith.

PLATE 23

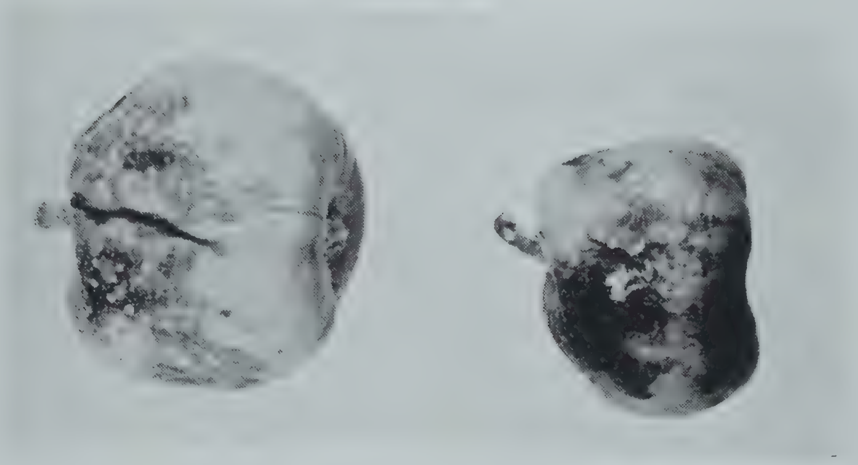


FIG. 53.—Superficial cork. Jonathan.

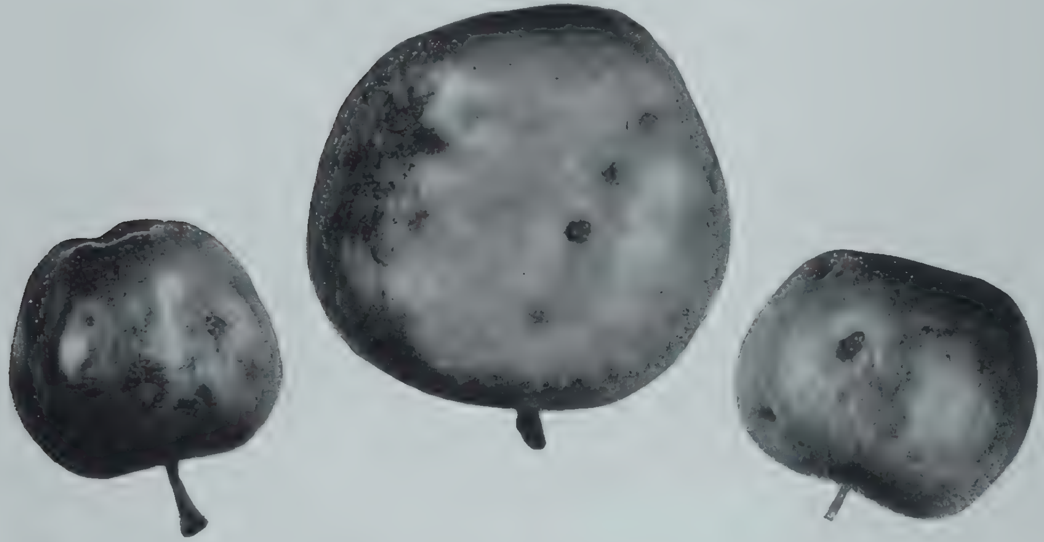
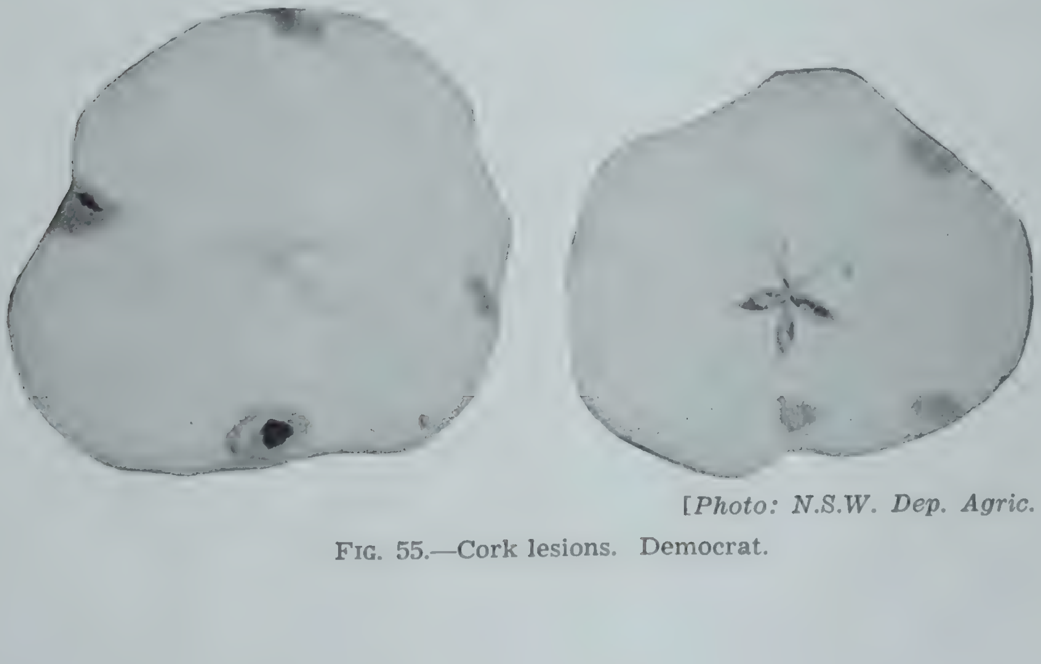


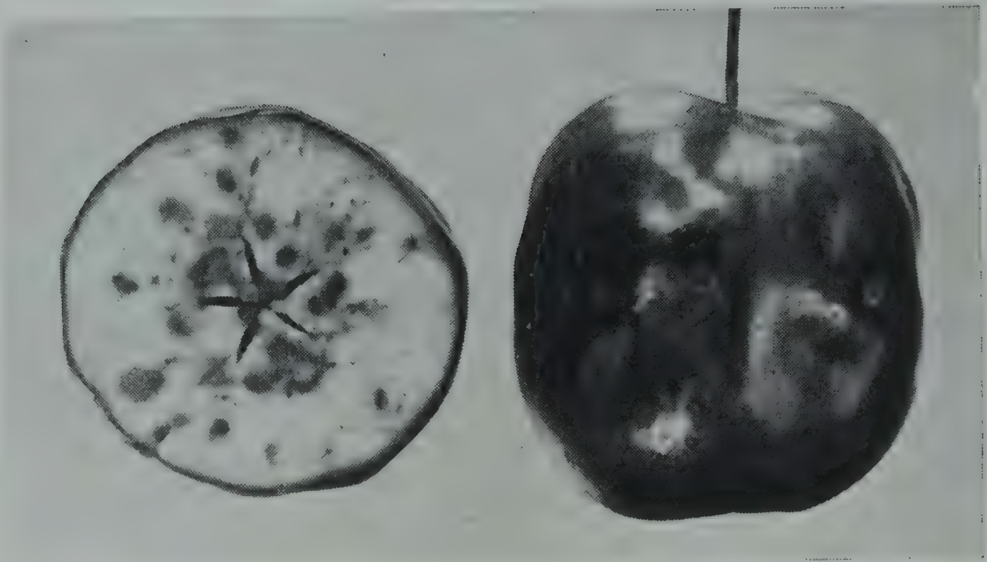
FIG. 54.—Superficial cork and cork. Cox (centre), cork only. Jonathan (left and right)



[*Photo: N.S.W. Dep. Agric.*

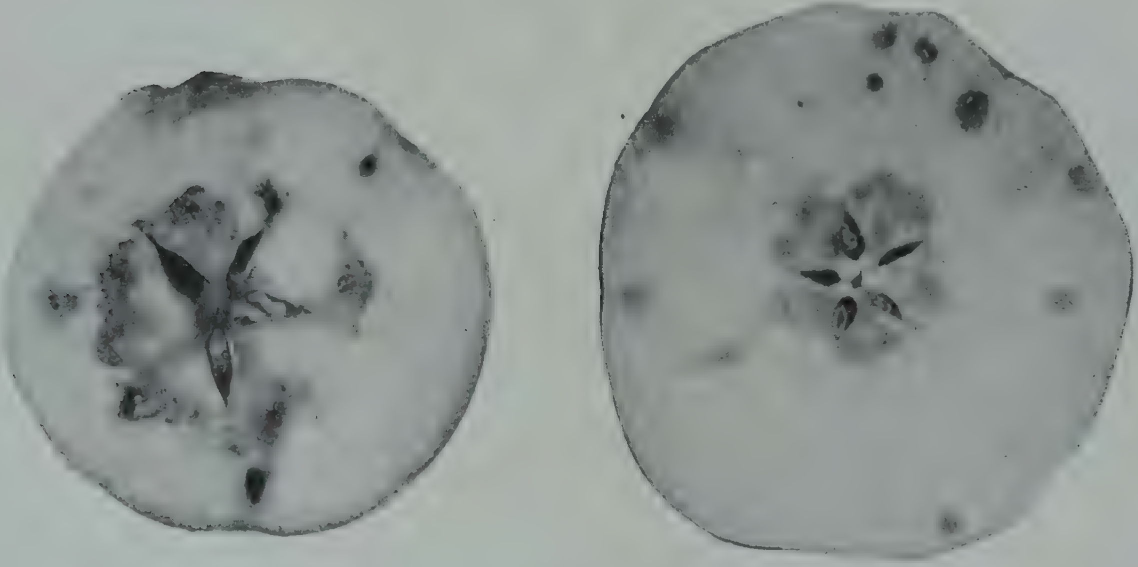
FIG. 55.—Cork lesions. Democrat.

PLATE 24



[*Photo: D. Martin.*

FIG. 56.—Internal cork. Sturmer. Showing malformation.



[*Left photo: Dom. Canada Dep. Agric.*
[*Right photo: N.S.W. Dep. Agric.*

FIG. 57.—Internal cork and corky core. Pomme de Neige (left), Granny Smith (right).

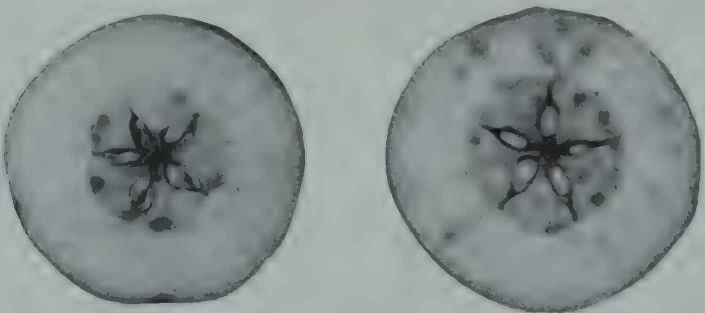


FIG. 58.—Corky core and internal cork. Jonathan.

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